The contribution of William, Lord Armstrong to science and education

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ABSTRACT OF THESIS

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THE CONTRIBUTION OF WILLIAM, LORD ARMSTRONG TO SCIENCE AND EDUCATION.

William George Armstrong (1810-1900) is best remembered as the lawyer turned engineer who revolutionised ordnance during the Crimean War. Nonetheless, his researches, his evidence before Royal Commissions and his presidential addresses, (including that to the British Association for the Advancement of Science), are as relevant today as they were last century. Indeed, it could be argued that whereas George and Robert Stephenson were, essentially, men of the Industrial Revolution, Armstrong's theories are still appropriate in the space age. Apart from his extensive research into hydraulics and electricity, which greatly advanced the frontiers of science, his contribution to education is considerably more than a mere footnote to his more spectacular achievements.

At a time when the men of theory and the men of practice despised each other, Armstrong stood athwart the debate. Instead, he built an educational and industrial complex at Elswick where theory and practice went hand in hand and which became the blue-print for successive Royal Commissions. While others argued for technical education on continental lines, Armstrong upheld the Elswick example.

His reluctant involvement in the proposed College of Physical Science in Newcastle upon Tyne is the subject of some debate in this study. Nonetheless, when he was finally convinced of its efficacy, his support was unequivocal. So much so that, after his death, the resultant edifice became Newcastle's abiding memorial to him.

Two recent biographies have been used as works of general reference, but the main thesis rests on extensive use of original material. This includes Armstrong's speeches and writings; his evidence before Royal Commissions and the records of the Elswick Works' Mechanics' Institute and Schools.

Hitherto, Armstrong's fame has rested on his weapons which destroyed human life. His greatest weapon - his contribution to science and education - which destroyed the 'laissez faire' attitudes of his contemporaries, has been largely ignored. In an endeavour to redress the balance, this study has been attempted.

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CONTENTS.

		Page.
	STATEMENT OF COPYRIGHT	i
	ACKNOWLEDGEMENTS	ii
	ABBREVIATIONS	iii
CHAPTER I	EDUCATION IN NEWCASTLE AT THE TIME OF THE REFORM ACT OF 1832.	1
CHAPTER II	THE DEVELOPMENT OF INDUSTRY ON TYNESIDE. THE DETERMINANTS OF ARMSTRONG'S CAREER.	27
CHAPTER III	THE SCIENTIFIC COMMUNITY IN NEWCASTLE FROM 1832 TO 1848.	48
CHAPTER IV	FROM LAWYER TO ENGINEER. ARMSTRONG'S CAREER FROM 1832 TO 1846.	74
CHAPTER V	ARMSTRONG OF ELSWICK, 1847 - 1863.	111
CHAPTER VI	ARMSTRONG AND THE ELSWICK MECHANICS' INSTITUTE, 1848 - 1863.	149
CHAPTER VII	ARMSTRONG AND THE WIDER SCIENTIFIC COMMUNITY.	184
CHAPTER VIII	SOME WIDER ASPECTS OF ARMSTRONG'S LIFE AND WORK.	218
CHAPTER IX	FIERY PITS AND SPORADIC ENLIGHTENMENT.	253
CHAPTER X	A FITTING INSTITUTION IN THE HEART OF A COALFIELD?	291
CHAPTER XI	ARMSTRONG'S ELSWICK SCHOOLS PART I BOYS' DEPARTMENT.	335
CHAPTER XII	ARMSTRONG'S ELSWICK SCHOOLS PART II GIRLS' DEPARTMENT.	371
CHAPTER XIII	ARMSTRONG'S LATER YEARS.	390
CHAPTER XIV	ARMSTRONG AND SAMUELSON.	430
CHAPTER XV	THE SCIENTIFIC AND TECHNICAL DEBATE. PLAYFAIR VERSUS ARMSTRONG.	455
CHAPTER XVI	"THE IMMENSITY WHICH LIES BEYOND".	490
	APPENDICES I - IX	517
	BIBLIOGRAPHY	539

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Tyne and Wear Archives, Newcastle upon Tyne.

Universities of Durham, Edinburgh and Newcastle upon Tyne, Main and Education Libraries and Archives.

ABBREVIATIONS

B.A.	British Association for the Advancement of Science.
B.J.E.S.	British Journal of Educational Studies.
E.W.L.M.I.	Elswick Works' Literary and Mechanics' Institute.
I.C.E.	Institution of Civil Engineers.
I. Mech E.	Institution of Mechanical Engineers.
Lit & Phil	Literary and Philosophical Society of Newcastle upon Tyne.
N.A.P.S.S.	National Association for the Promotion of Social Science.
N.E.I.M.E.	North of England Institute of Mining Engineers.
N.E.I.M.M.E.	North of England Institute of Mining and Mechanical Engineers.
n.d.	No date.
N.S.	New Series.

CHAPTER I.

EDUCATION IN NEWCASTLE AT THE TIME OF THE REFORM ACT OF 1832.

The architect of the Reform Bill passed in 1832 was Charles, Earl Grey, the Whig Prime Minister and scion of an ancient aristocratic Northumbrian family. At the same time, another Northumbrian, William George Armstrong, came of age and soon returned home after studying Law in London. Later to become as renowned in science and engineering as Grey was in politics, Armstrong made the provision of scientific and technical education one of his major concerns. What, then, was the state of education in his native Newcastle upon Tyne at the time of his majority?

Before 1832, Parliament generally showed little concern for the education of the poor. The exception was the so called 'education mad' party, mostly Whigs, who, led successively by Whitbread, Brougham and Roebuck, fought in and out of Parliament from the beginning of the nineteenth century for a greater measure of State involvement in the education of the people. In the first session of the Reformed Parliament of 1833, Roebuck introduced an Education Bill with visionary and wide ranging terms, which obliged by law 'every child from perhaps 6 years of age to 12 years of age to be in regular attendance at school', and compelled the parents 'to send the child to a school of the State'. (Hansard, Parliamentary Debates, Third Series, Volume XX, Column 153, 1833).

Opposition to Roebuck's Bill came from the two main groups of protagonists who were to impede the establishment of a national system of education until the eventual passing of the 1870 Education Act. On one side, the supporters of the voluntary system argued that taxes should not be levied 'in order to teach the working classes reading and writing'. (Hansard, Vol XX, Column 735, 1833). On the other, the Church of England claimed that they had the right to control education. Brougham, then Lord Chancellor, spoke on both issues. First he argued that the voluntary principle was a success, and that the State system was 'wholly inapplicable to the present state of the country and the actual state of education'. (Report from the Select Committee on the State of Education of the People of England and Wales, 1834, item 2821). Then, recognising that little common ground existed between Church and Dissent, and that the 'religious difficulty' in education was only one aspect of a wider issue, he summarised the situation thus:

> 'The Church wished for education, but they wished to keep down the sects a little more. The Dissenters wished for education, but they wished to pull down the Church a little more.' (Hansard Volume L, Column 594, 1839).

Despite such antagonism, an important watershed was reached when, on 17th August, 1833, Parliament allocated £20,000 for educational purposes. (Hansard Volume XX, Column 736 1833). This money was to be used specifically for the erection of school buildings. Moreover, in the absence of an appropriate Government department, it was to be administered by the two voluntary agencies concerned with the education of the poor - the National Society and the British and Foreign School Society. Subsequently, a Committee of the Privy Council for Education was created by Orders in Council, in 1839.

Almost from its inception, the Committee had obtained the able services of Dr James Kay (later Sir James Kay-Shuttleworth) to be its secretary. He introduced the system of issuing the Committee's directives in the form of Minutes of which two are relevant in the context of Armstrong's schools. The first, issued in June 1839, indicated that all future building grants to schools carried the right of Government inspection. (Minutes of the Committee of Council, 24th September, 1839). The other, issued in 1846, announced a scheme for the training of teachers, whereby monitors would be replaced by pupil teachers. (Minutes, August 25th 1846, and December, 1846). Thus, almost within the first decade of the Reformed Parliament, the foundations were laid for the modern State system of education, controlling then, as now, the building of schools; the educational grants; the right of Government inspection and the professional education of teachers.

Meanwhile, in the context of these national issues, what educational provision existed in Newcastle at that time? The reform movements, the increasing educational opportunities and the industrial developments brought in their wake an interest in politics and natural philosophy which engendered a demand for books, lectures and debates on the more serious subjects from all sections of the population. (S. Middlebrook, Newcastle upon Tyne. Its Growth and Achievement, 1968, p. 154). As a result, learned societies were formed in Newcastle as elsewhere until, by 1815, the number of libraries in the town had increased considerably and included several connected with the various places of worship, especially St Nicholas' Church and the Unitarian Chapel. Among the most famous institution formed, in consequence, was the Newcastle Literary and Philosophical Society, founded in 1793. (R.S. Watson, The History of the Literary and Philosophical Society of Newcastle upon Tyne, 1793 - 1896, 1897, p. 25). Both Armstrong and his father were distinguished members and generous supporters throughout their long association with the

Society.

Formal educational opportunities for young people in Newcastle were similar to those existing elsewhere, and included Charity Schools, Sunday Schools and Infant Schools for the lower classes and Private Academies and a Free Grammar School for middle class pupils.

The first Sunday school in the town was opened in 1784 by the Rev. William Turner, assisted by some of the young members of his congregation at the Unitarian chapel in Hanover Square, which already had its own charity school. Turner, at that time aged 23, had just begun his ministry in Newcastle which was to span the next half century. Educated at the Dissenting Academy at Warrington, he followed the traditions of his fraternity by involving himself in the main educational developments in Newcastle at that time. (R. Welford, Men of Mark 'Twixt Tyne and Tweed, 1895, Vol. III p. 543). In order to help his scholars with their studies, he wrote an 'Abstract History of the Bible', and opened a library for their use in the vestry of his chapel, in 1787. The Anglicans and the Methodists followed his lead, and by 1812, it was reported that scarcely a church or chapel existed without its Sunday school. (Middlebrook, p. 159).

Meanwhile, other developments were taking place in popular education which concerned Newcastle. These were the establishment of the Royal Jubilee schools and the infant school movement.

In 1810, in commemoration of King George III's Golden Jubilee, and in line with his express wish that 'every child in the kingdom should be able to read his Bible', schools for this purpose were established throughout the land. The Royal Jubilee School for Boys was founded in Newcastle near the Keelmen's hospital, in what is now City Road.
(J. Robson, "Royal Jubilee Schools, City Road, Newcastle upon Tyne,

1810 - 1967", Journal of the Institutes of Education of the Universities of Newcastle upon Tyne and Durham, Volume 21, Number 106, January 1970, pp. 87-89).

Once the school was successfully established, a similar one was opened in 1812 for about 200 girls, first in the Carpenters' Tower, near the Keelmen's hospital then, two years later, on a site in New Bridge street presented by the corporation. (Robson, p. 88).

Other important educational developments at this time included the establishment of infant schools. Promoted by Robert Owen at New Lanark in 1816, and encouraged by Brougham, the movement spread throughout England from 1818 onwards, and by 1825 had reached Newcastle. Here, the movement escalated largely because of the active support of local people, including the Editor of the Newcastle Courant, along with Alderman Henry Cramlington, who was serving his third term as Mayor, and James Losh. (Newcastle Courant, 22nd January and 19th February, 1825). The last named was destined to become Recorder of Newcastle and was, at the time, active in the reform movement and in the education of the poor. (Welford, Vol III, p.86).

The Newcastle Infant School Society was formed with the Duke of Northumberland as its Patron and the Mayor its President. (Newcastle Courant, 19 February, 1825). The Society opened its first school in the Orphan House in Northumberland Street, which was rented from the local Methodists. The Orphan House was originally designed by John Wesley as a school for 40 poor children where boys were taught reading, writing and arithmetic, and the girls, in addition to the three R's, were taught needlework. (W.W. Stamp, The Orphan House of Wesley, 1863, p. 25).

Meanwhile, a second infant school, for about 156 children, was opened in 1826 at the Sallyport Meeting House near the quayside, while a third 'for the children of the parents in the middle ranks of life' was opened privately in Albion Street. (E. Mackenzie, A Descriptive and Historical Account of Newcastle and Gateshead, 1827, p. 456).

This evidence seems to show that, under the voluntary principle, a number of schools, aimed specifically at the education of the poor, already existed in Newcastle at the time of the Reform act in 1832.

Like many other towns, one of Newcastle's oldest and most notable schools was the Free Grammar School of Queen Elizabeth, which, for almost forty years, from 1749 to 1787, had won a particularly high reputation for scholarship under the direction of its headmaster the Rev. Hugh Moises. (R.J. Charleton, Newcastle Town, 1978, p. 138). In those years, some of the most distinguished and brilliant pupils attended the school, including Admiral Lord Collingwood and the two Scott brothers, William, Lord Stowell, and John, Lord Eldon, who became Lord Chancellor of England. (Charleton, p. 140). At that time, the school still followed the traditions of the other Tudor Grammar Schools, in which the classics formed the core curriculum.

Unfortunately, the numbers at Newcastle Grammar School steadily declined, especially after the retirement of the Rev. Hugh Moises, until by 1820 there were only nine boys in attendance compared with 130 a generation before. (Middlebrook, p. 217). At the Mayor's request, a commission of enquiry considered the school's future. The result was a complete reorganisation into a lower or writing school for boys under eight years of age, and an upper school for the remainder. At first these innovations caused the numbers to rise to eighty by 1826, but by 1834 they had fallen again until only fifteen remained on the roll. (Middlebrook, pp. 216-217). This, unfortunately, was typical of a national trend. The inability, or the unwillingness of the grammar schools and the two ancient English universities to adapt their curriculum to meet the educational needs of the emerging industrial society, coupled with the constraints of the Test Acts, impeded educational progress until well into the nineteenth century. (N. Hans, New Trends in Education in the Eighteenth Century, 1966, p. 37). As a result, the nonconformists, and those who desired a more liberal and scientific education, had to attend one of the private academies like those run by the Dissenters, and a university either in Scotland or on the Continent for example at Leyden, in Holland. (Hans, p. 24).

Even Durham University, founded in 1832 in the heart of one of the country's largest coalfields, failed to meet the obvious scientific needs of its industrial environment. Thus, it is through Armstrong's appreciation of the need for scientific and technical education in modern industrial society that his work will be assessed.

One school in Newcastle which did have a scientifically based curriculum, and which, in consequence, won high renown among the middle classes, was the Academy in Percy street founded in 1805 by John Bruce. It was ably directed by him until his death in 1835, and, thereafter, until 1859, by his son Dr J. Collingwood Bruce. (Charleton, p. 361). The school finally closed in 1881, but its list of distinguished pupils included the Tyneside engineers Robert Stephenson, Charles Mark Palmer, and Isaac Lowthian Bell as well as the chemist Thomas Richardson. (Archibald Reed, Bruce's School, 1903, p. 113).

Not surprisingly, the school's reputation at that time was far in excess of the Free Grammar School. Indeed, this situation accords with an address given in Perth Town Hall, as early as 1760:

> 'The people of England have private academies established in almost every great town where not only the languages but the sciences, which are of the greatest use in life are taught in a practical manner'. (T.C. Smout, A History of the Scottish People,

1560 - 1830, 1975, p. 446).

Unfortunately, there is no evidence to suggest that any girls' school in Newcastle had a comparable curriculum at that time. Indeed, there seem to have been a number of private day and boarding schools for girls where the curriculum was as constrained as that of the charity schools, with the dual emphasis on moral and religious instruction, and on education for a specific social role. These schools, catering as they did for girls of 'gentle birth' stressed such accomplishments as 'address' and deportment, as well as music, dancing and, sometimes, French. Nevertheless, they were, by the standards of the day, acknowledged to be 'well attended and ably conducted'. (Mackenzie, p. 460). Since, by tradition, the girls were being educated solely for domestic duties, whereas boys of similar social class were destined for careers in commerce, industry and the professions, their schools reflected these aims. The curricula of the boys' private schools, like that of Bruce's Academy, were much more educationally demanding, and, apparently, placed great emphasis on mathematics and accounts.

A contemporary Newcastle writer observed that: 'on the whole, there is not a town in England where the means of obtaining a good education are better or more various'. (Mackenzie, p. 460). Certainly the foregoing evidence seems to substantiate this, but only in the context of the prevailing social norms. This was the age of philanthropy, patronage, and 'laissez faire', when social stratification was at its most entrenched. Thus, in 1832, the educational provision in Newcastle, as elsewhere, reflected this view. The era of equality of opportunity and of upward social mobility, apart from a few notable exceptions, had yet to dawn.

Nevertheless it could be argued that those who were to alter the situation were already alive at the time of the Reform Act. Given this premise, who were they, what educational opportunities did they have and how did they influence events?

Within the context of this study, four men from the North East have been chosen as representatives of a wider whole.

At the time in question, Tyneside was already emerging as an engineering centre in a number of fields, but most notably through the development of the railways by George Stephenson and his son Robert who, being born in 1803, was Armstrong's contemporary. Meanwhile another contemporary, Algernon George Percy, Lord Lovaine, (1810 - 1899), son of the Earl of Beverley and ultimately sixth Duke of Northumberland, had followed his father as Member of Parliament for the family borough of Beeralston in 1831, but had lost his seat a year later under the terms of the Reform Act. Meanwhile, Armstrong was following a legal career prior to starting his more famous enterprise as an engineer on Tyneside.

These men - the two Stephensons, Percy and Armstrong - despite their differing social origins, were to dominate the industrial, political and social life of North East England in the nineteenth century. Not surprisingly, their education was as divergent as their upbringing. Indeed, drawn as they were from the humblest to the noblest levels of society they serve as a case study of the social stratification existing within the educational system of the time.

Although the education of the three contemporaries forms in itself a discrete study, the education of Robert Stephenson can only be thoroughly understood in the context of his father's lowly origins and consequential ambitions for his son. As one researcher has observed:

> 'No parent ever displayed more interest or more intimate concern over his son's education; no crammer ever kept a boy's nose to his

books more assiduously'.
(L.T.C. Rolt, George and Robert Stephenson, 1978, p.15)

The reason for this is not hard to find. George himself was born of humble parents, but was both brilliantly practical in the mechanical arts and intensely ambitious. Robert was to be the embodiment of that ambition. His father could teach him practical skills, but his final education had to give him the theoretical knowledge of engineering his father lacked. Unlike many children whose choice of school is largely determined by background, by environment or by family tradition, Robert Stephenson's education was deliberately planned from beginning to end by his father. (William Lockey Harle, "George Stephenson. Memorial to Genius", Lecture 1866). This was probably because George realised the shortcomings of his own education which he never overcame, due in part to his ill-concealed contempt of theorists and scholars and his inability or unwillingness to communicate other than in a broad, often unintelligible, Northumbrian dialect. (Harle p. 14)

How far was he the legendary 'unlettered pitman' whose native genius made him one of the most renowned engineers in history; how far did this influence his plans for Robert, and how far was he successful?

George was the second son of a miner who worked at Wylam Colliery on Tyneside for 12 shillings a week (Rolt p. 6) and later in one of the Duke of Northumberland's collieries near Newburn. (Welford, Vol III p. 437). Like many of his class at that time, George received no schooling whatsoever and even by the time he was eighteen he could neither read nor write. (W. Duncan, Ed. The Stephenson Centenary, 1881, p. vii).

It was during George's lifetime that mechanical engineering began to emerge as a profession from the practice, by artisans and mechanics, of an art based on intuitive trial and error. Although the early engineers did not scorn scientific knowledge, they tended to work with what became known as 'mechanical instinct', believing that the eyes and fingers were the best judges of accuracy. Nasmyth himself maintained that 'the nature and propensities of the material come in through the finger ends'. (S.G. Checkland, The Rise of Industrial Society in England, 1815 - 1885, 1982, p. 74). Only gradually did scientific method and design research develop to give rise to the modern professional engineer. This evolution was as much the concern of education as it was of industry - a concern which Armstrong made his own.

For his part, George Stephenson was the archetypal mechanical genius of the first industrial revolution whose outstanding results owed more to sheer practical skill and application than to scientific principles. Thus, by working out in practice those principles which others had already overcome in theory, he soon won fame among the engineering fraternity through his ability to solve problems beyond the capabilities of those with greater scientific knowledge. (Rolt p. 14)

Some years later, when he and Robert were constructing the Liverpool to Manchester Railway, George's proposed route over the swamp known as Chat Moss was described as: 'ignorance almost inconceivable ---'. Indeed his critics declared that : 'Every part of the scheme shows that this man has applied himself to a subject of which he has no knowledge and to which he has no science to apply'. (S. Smiles, Lives of the Engineers, George and Robert Stephenson. 1904 p. 199). Despite this criticism, he overcame the problem by laying that part of the line on an elongated raft. Nevertheless, he readily acknowledged that intuitive ability was insufficient to meet the new technical developments and that the educational facilities were inadequate to meet the needs of the aspiring artisan and the ambitious mechanic. For this reason, he became not only one of the leading supporters of the Mechanics' Institutes, but he devised what he considered to be an appropriate course of instruction for his son. In his view, Robert should be an engineer and a director of labour, who should not have his exertions baffled by defective knowledge. As a result, George developed a working partnership with his son whereby he would master the practical skills in any enterprise, and Robert the literary and theoretical ones. To this end, Robert was sent first to the village school near his Killingworth home, (Rolt p. 15) and later to Bruce's Academy in Percy Street, in the centre of Newcastle, some five miles away. (Reed p. 71).

At that time, the hundred pupils attending the school, many of whom were destined to be among the region's civic, industrial and judicial leaders, were described as 'a good style of middle class boy (of whom) some few were the sons of the minor gentry of the vicinity, but the majority were the sons of (local) professional men and traders. (Reed p. 17). Thus, in this one move, George secured the upward social mobility he so ardently desired for his son.

Nonetheless, Robert had to face problems in adjusting to his new status. The young boy from a colliery village, speaking the local dialect, had to endure the taunts of those boys who regarded him as their social inferior, but his good nature and application to his studies soon overcame this problem. (Reed p. 17).

At this time the school enjoyed an excellent reputation. A contemporary of Stephenson averred that : 'Mr John Bruce had raised his school to such excellence that it ranked higher than the Newcastle Grammar School where Lord Stowell, Lord Eldon and Lord Collingwood received their early instruction', while another contemporary recalled that from what he remembered of the curriculum, it carried both classics and mathematics. (Reed p. 40). Even so, Robert Stephenson was among a large number of boys who studied neither Greek nor Latin, although he was allowed to learn French, because it would be useful to him in his future business contacts. (Reed p. 19).

Until he left Bruce's Academy, Robert did not exhibit any marked enthusiasm for those pursuits in which his father was most keenly interested. Nevertheless when Robert was at the height of his own illustrious career as an engineer, he paid this tribute to his former headmaster, on the occasion of the Jubilee Dinner of Bruce's Academy:

> 'Indeed it is to his tuition and methods of modelling the mind that I attribute much of my success as an engineer. It was from him that I derived my taste for mathematical pursuits and the faculty I possess of applying this kind of knowledge to practical purposes and modifying it to circumstances'. (Reed p. 39).

It could be argued that the Stephensons developed their own scheme of mutual instruction during Robert's attendance at Bruce's Academy because the latter spent his spare time at the Newcastle Literary and Philosophical Society and recounted the results of his reading to his father on his return home. (Harle p. 16). Sometimes he was allowed to take home a copy of the Repertory of Arts and Sciences, which he and his father studied together, although many equally valuable books were for reference only. Robert studied these in the library and brought home sketches and notes for his father's information. In turn, George taught him to read plans and drawings without written descriptions, frequently stating:

'A good plan will always explain itself'. (Smiles p. 64).

George would then produce a drawing of an engine or machine, and ask Robert to describe in detail both the arrangement and the action. Thus he taught his son to read from a plan as easily as from a book, an experience which enabled him to comprehend, with great facility, the details of even the most complicated mechanical drawings.

While Robert prepared his homework in the evenings, George worked at his model engines or studied the latest mechanical inventions. Through his example a spirit of self improvement was developed in Robert, which continued throughout his life. Even to the end of his career, the son acknowledged the debt he owed to his father for his professional success. (Smiles p. 65).

Early in October 1821, George Stephenson was ordered to proceed with the survey of the Stockton and Darlington Railway. (Rolt p. 69). At this time, Robert was 18 and had not yet completed his apprenticeship at Killingworth Colliery with Nicholas Wood, whose concern for the College of Physical Science is noted later. Nonetheless, George asked for his release so that he could help with the survey and this was agreed. Young though he was, Robert had already gained considerable experience in helping George to lay out several local colliery lines. Thus he was well qualified not only to act as assistant to his father but to survey on his own account and even to deputise for him on Parliamentary business.

In October 1822, Robert, at his father's suggestion, agreed to spend six months at Edinburgh University, (Rolt, p. 2), which was then at the height of its reputation, both in intellectual achievement and in the variety of the subjects offered. (Smout p. 353). At Edinburgh, Robert studied natural philosophy, natural history and chemistry and joined his fellow students on a geological survey of the Scottish coast. (Rolt p. 92). Although this academic interlude could have been a welcome break after the problems of surveying and constructing railways, it was too short to have any lasting effect. Perhaps George's practical tuition and Robert's own not inconsiderable experience as an engineer made him less than receptive to the theoretical teaching of a University, no matter how distinguished. Indeed, as Smout has observed:

> 'How far the academic tradition directly enriched technology in the industrial revolution is doubtful, apart from the single instance of Watt and Black. Although in industrial chemistry, some important advances were made by men who had attended chemistry classes at Glasgow or Edinburgh, in the end little of practical value was produced by the university chemists compared with what industry could achieve for itself'. (Smout p. 455).

This view accords with Robert's own and he left Edinburgh in April 1823 less than satisfied with the tuition he had received. By June, at only twenty years of age, he was managing his own locomotive works in Newcastle. (Rolt p. 92).

Partnership between father and son was now on terms of equality. Thus, they won international renown and gained the reputation that 'they laid the foundations of the modern world and all our subsequent achievements'. (Rolt p. 335). Despite Robert's fame as a civil engineer, the development of the steam locomotive was his greatest accomplishment. (Rolt p. 320). Thus, like his father, mechanical engineering was his true vocation.

Towards the end of his life, when he was one of the world's leading engineers, he became involved in politics and was returned unopposed as Tory M.P. for Whitby in 1847, a seat which he retained until his death. (Rolt p. 324). In 1859 he expressed some views on the education of the working classes, which appear both remarkable and provocative in the context of his own humble origins and privileged education. (Rolt p. 325). He opposed Lord John Russell's educational reforms on the subject and opined that: 'What the artisan wants is special education for his own particular speciality, and the more he leaves everything else alone, the better'. His contemporary and rival, Brunel, went even further by stating that he preferred his enginemen to remain illiterate, as formal education only caused their minds to wander from the responsible job in hand. In the event, Robert's deeds did not match his words. Not only had he declared his indebtedness to his former school only four years earlier, but he was a generous benefactor to the Newcastle Literary and Philosophical Society where he had studied as a boy. He donated £2000 to clear the debt incurred by the institution and had already drawn up his Will wherein he left it a handsome legacy of £7,000. Overwork and the constant strain of responsibility combined to ensure his untimely death, at the age of 56, in October 1859. To few commoners were such public marks of respect accorded as to Robert Stephenson. On the day of his funeral, shipping on the Thames, Tyne, Wear and Tees was silent, and flags flew at half mast. (Norman McCord, North East England, the Region's Development 1760 - 1960, 1979, p. 56). On Tyneside all business, including Armstrong's, ceased at noon. From his Forth Street Locomotive Works, which he had first managed as a young man on his return from Edinburgh University, the 1500 workers, at their own request, marched to a memorial service in the nearby church of St Nicholas. Not only was he buried in Westminster Abbey but, with the Queen's permission, the funeral cortege was allowed to pass through Hyde Park.

Unlike Armstrong, who was buried in the quiet churchyard at Rothbury, an Abbey burial was also accorded to Algernon George, sixth Duke of Northumberland, in 1899, not through achieved status, but as head of the Percy family who enjoy that distinction in perpetuity. By contrast with their obsequies, the origins of Percy and Stephenson could not be more different. Shortly before his birth, Robert Stephenson's grandfather earned 12 shillings a week working in a mine owned by Algernon Percy's great uncle the second Duke of Northumberland, yet by

1850, through his own endeavours and those of his father, Robert's income was assessed at £30,000 per annum, 'equal to the patrimony of many an aristocratic family'. (McCord p. 56).

Few could have been born to a greater inheritance of privilege and power than Algernon George Percy, politically, economically and socially. Politically, he belonged to that close knit oligarchy of whom it was said that :

> 'Whig and Tory, that is a few great families with their connections and dependents -- play out the political game in their own way and for their own benefit'. (The Westmister Review, Vol. I, January - April, 1824, p. 2).

Like William George Armstrong, (1810-1900), Algernon George Percy's life spanned almost all but the first ten years of the nineteenth century. During that time, the foundations of modern society were laid, as industry rapidly developed and the non-rural population increased, bringing an increasing demand for food, consumer goods and raw materials. Shrewd landowners, aware of the economic potential of these new markets, readily invested not only in agricultural improvements on their immediate estates, but in the transport developments of road, canal and rail, which formed the essential infrastructure of wider industrial expansion. (Richard Tames, Economy and Society in Nineteenth Century Britain, 1972, p. 59).

Equally, when the industrial revolution increased the demand for coal, the landowners developed the mineral resources on their estates. Thus, even when the Corn Laws were having their greatest effect on agriculture, the landowners could offset these losses against their profits from transport, urban rents and mineral workings. (Tames, p. 65).

The Dukes of Northumberland were among those whose family fortunes depended as much on coal and transport as on agriculture.

(J.F.C. Harrison, Early Victorian Britain, 1832 - 51, 1971, p. 125). Like others of similar class, judicious investment in docks, harbours and property in the rapidly growing industrial towns on their estates further ensured that they shared in the wealth created by the new middle classes. As Harrison has observed:

> 'Although landed wealth declined, relative to other forms of wealth in the nation at large, the aristocracy was able to maintain a high level of material prosperity and to assert its traditional role of a ruling elite throughout most of the nineteenth century'. (Harrison, 1971, p. 125).

This was the world of power and privilege into which Algernon George Percy was born and in which he lived his life. What was his history, how was he educated, and how did he contribute to the social and educational developments of his time?

Born in 1810, Algernon George Percy was the son of Lord Lovaine and the grandson of the Earl of Beverley whose father, as Sir Hugh Smithson, had married Lady Elizabeth Seymour. She in turn inherited the vast Percy estates and became Baroness Percy in her own right. Her husband adopted the name of Percy and in 1766 became the first Duke of Northumberland of the third creation, with succession to his eldest son. (George Tate, The History of the Borough, Castle and Barony of Alnwick, 1866, Vol I, p. 357). On 26th January 1784, another peerage was added to the family titles when he was created Lord Lovaine, with remainder to his second son, Lord Algernon Percy. (Tate, p. 357).

The latter first entered Parliament for the county of Northumberland in 1774 at the age of 24, and succeeded his father as second Baron Lovaine in 1786. Politically, he was a Tory and did not approve of the extreme Whig views of his elder brother, Hugh. (Gerald Brenan, A History of the House of Percy, 1902, Vol II p. 463). In recognition of his services to the administration, he was ennobled by Pitt in 1790, assuming the title of the Earl of Beverley.

On his death in 1830, his son, George, Lord Lovaine, succeeded to the earldom. The latter's son, Algernon George Percy, in turn became Lord Lovaine and M.P. for Beeralston, but was disfranchised under the terms of the first Reform Act of 1832. (Brenan, Vol. II p. 467). In preparation for this destiny, his education had followed the traditions of his class in general and of his family in particular. In the wake of successive Percys, he was educated at Eton and at St. John's College, Cambridge, of which University, his father's cousin, Hugh, third Duke of Northumberland, was Chancellor. (Tate, Vol. I p. 363).

No further records of Lord Lovaine's subsequent Parliamentary career have been traced, until he unsuccessfully contested the northern division of Northumberland in the election of August 1847. (Tate, Vol I p. 480). Nevertheless, he was returned for that constituency in the 1852 election and continued to represent it in the Conservative interest until 1865, when his father became fifth Duke and his son represented it thereafter. (Tate Vol I p. 473).

Having served as a Captain in the Grenadier Guards, (R.W. Martin, Northern Worthies, Vol. I), Lord Lovaine continued to take a deep interest in military matters as a Member of Parliament whose opinions were always noted with great respect. (Skelly, p. 25). He held Office as Lord of the Admiralty in 1858, as Vice President of the Board of Trade in 1859 and, after becoming Duke, as Lord Privy Seal from 1878 to 1880 in the last administration of Lord Beaconsfield. (Archaeologia Aeliana, Third series, Volume X, Centenary Volume, 1813 - 1913, p. 270). In August 1878, he was appointed President of the Royal Commission inquiring into the Parochial Charities of the City of London. (Martin Vol I).

Meanwhile, the succession to the dukedom having failed in the direct line with Algernon the fourth Duke, Lord Lovaine's father, the Earl of Beverley, succeeded his cousin in 1865 at the age of 87. His advanced years, and the brevity of his dukedom, prevented George Percy from participating in public life and continuing the expansion of the estates as established by the first Duke and continued thereafter by his successors. These traditions were to be inherited by his heir, first as Earl Percy and, two years later, as sixth Duke of Northumberland. Succeeding as he did in middle age, Algernon George Percy had both the personal maturity and the public experience of a long Parliamentary career to enable him to continue the reforms undertaken by his predecessors. Wide ranging though his interests and responsiblities were, he evinced a particular concern for the education and social improvement of the working classes in the area.

In addition to his patronage of schools, Algernon George Percy supported a number of projects aimed at improving the social conditions of the local working classes. The Alnwick Scientific and Mechanics' Institute was among the earliest to be founded, having originated in 1824. From the outset, the Percy family was associated with its progress, with successive Dukes becoming President. For his part, even while he was Lord Lovaine, Algernon George Percy was described as a 'generous donor' to the Institute's library in 1863, and, as President, he was untiring in his efforts to promote its welfare. (<u>Minutes of the Alnwick Scientific and Mechanics' Institute,</u> 1863). When the premises were enlarged, the new Duke gave £50 of the £200 required for the building.

For his part, William George Armstrong was born neither to the extreme poverty of the Stephensons, nor to the noble affluence of the

Percys. His father, also William, was born in 1778, and came from yeoman stock, originally from Wreay in Cumberland. (E.R. Jones, Heroes of Industry, 1886, p. 11). It was while he was still a young man, some time in the 1790s, that William senior came to Newcastle to work as a clerk with a firm of corn merchants, Messrs Losh, Lubbun and Co. (Peter McKenzie, W.G. Armstrong, 1983, p.11). His talent and enterprise resulted in a partnership with the firm and, when the senior partners retired, he became the sole owner, trading under the name of William Armstrong and Co. (David Dougan, The Great Gunmaker, 1970, p. 20).

Although this was singularly fortunate for Armstrong senior, he was a remarkable young man. Those who, like him, could read and write at that time, some seventy years before elementary education was compulsory, were in the minority. (Dougan p. 20). His early interest in education prompted him to join the newly formed Literary and Philosophical Society, shortly after his arrival in Newcastle. Here, he made several useful contacts, and it was possible that here he met his future wife, Ann. She was the daughter of William Potter of Walbottle Hall, in Northumberland, and was a highly cultured woman. (McKenzie, p. 11). Armstrong senior was a keen mathematician who contributed to mathematical magazines and collected a large number of books on the subject. When he died, he bequeathed this collection of over 12,000 volumes to the Literary and Philosophical Society, thereby endowing it with the most comprehensive library of its kind outside of London. His other interest was in Natural History, and he became one of the founders of the Natural History Society of Northumberland, Durham and Newcastle upon Tyne. (McKenzie, p. 11).

At about the time of the passing of the Municipal Corporations Act, when Armstrong senior was approaching sixty, he became active in local politics. The new legislation, in which he took a keen interest, extended the franchise to include all ratepaying households, and enlarged the boundaries of certain towns. In Newcastle, this meant the inclusion of the hitherto separate villages of Westgate, Elswick, Jesmond, Heaton and Byker. Standing as a candidate for the new Jesmond Ward in 1836, Armstrong won an easy victory. (Dougan, p. 21). When approaching 65, and still involved in Council affairs, he became concerned with the further development of the River Tyne as a commercial enterprise. He wrote two pamphlets on the subject and became Chairman of the River Committee, which later became the River Tyne Improvement Commission. In 1849, he was created Alderman, and the following year, aged 74, he became Mayor of Newcastle, and invited his daughter in law, Mrs W.G. Armstrong to be his Mayoress. (Dougan, p. 21). Although his son did not share these political commitments, some of his father's other interests were to continue into the next generation.

The son, William George Armstrong, was born in 1810 at No. 9 Pleasant Row, Shieldfield in Newcastle - a terraced house with three storeys and a large rear garden running down to Pandon Dene. As a boy, young William suffered from poor health, which the severe northern winters did little to dispel. Confined to the house for long periods, the child found no difficulty in amusing himself by making toy machines from old spinning wheels and other discarded household objects. He often tied weights to pieces of string and suspended them over the stair bannister to give them greater force and movement. His toys were regarded not simply for amusement but as items to be dismantled, and their working parts studied. In summer, at the home of his maternal grandfather, he frequented the nearby joiner's shop. Here he was allowed to make fittings for his machines, and, more importantly, he acquired the skill of using tools, an accomplishment he retained throughout his life. (Dougan, p. 24).

He was educated at a number of private schools, first in Newcastle and then in Whickham, near Gateshead, until, aged 16, he was sent as a boarder to the Bishop Auckland Grammar School, where he stayed with the Headmaster the Rev. R. Thompson. With the benefit of hindsight, it could be argued that the foundations of his future life were laid at Bishop Auckland. Here he first showed evidence of an interest in ballistics and engineering, and here he first met his future wife. One day, in search of amusement, he made himself a cross-bow and, using broken tobacco pipe stems as missiles, he fired them at the house opposite his lodgings. When several cracked windows resulted, the culprit was caught and duly punished. Yet, this juvenile venture into the world of projectiles was the start of a lifelong fascination with a subject on which both his fame and his fortune would largely rest. In the short term, a more acceptable preoccupation was found when the local engineering works of William Ramshaw claimed his attention. The boy's inherent talent for mechanics was encouraged by the proprietor, and Armstrong became a regular visitor, first to the works and later to the Ramshaw's home where he met their daughter, Margaret, the future Lady Armstrong.

As his schooldays ended, Armstrong began to consider a career. Left to his own devices, mechanics would have been his first choice. (Dougan p. 24). The subject had interested him from his early days, and now he was more fascinated by it than ever. Unfortunately, at that time, it was not a career that a socially ambitious father like William Armstrong would choose for his son. Despite the remarkable mechanical achievements in the collieries and in transport, it was still a somewhat nebulous and indefinite career. Furthermore, the men engaged in such endeavours were not, on the whole, the people of letters and culture whose society William senior had come to enjoy. Having risen from the harsher world himself, he had no desire to see his son returning to it. He wanted him to use his education as a ladder to a real profession. In this regard, he resembled George Stephenson, for although their chosen means were different, they wanted their sons to exploit fully the opportunities which, in youth, they had been denied.

One of the consequences of William senior's membership of the Literary and Philosophical Society was the opportunity to develop social and business contacts. In the context of his son's future career, his most important friendship was with Armorer Donkin, a local solicitor, whose own interests in literature and science had caused him to join the Literary and Philosophical Society in the first instance. As the friendship grew, the bachelor Donkin became like a second father to the Armstrong children Ann and William George. The children frequently visited him, and even spent holidays at his country house at Rothbury, in north west Northumberland. Could it have been here, at Donkin's home in Rothbury, that Armstrong's nascent love of science first blossomed? Certainly it was here, in the nearby River Coquet, that the young William indulged in his new found sport of fishing and became so adept that he became known locally as 'the kingfisher'. (McKenzie, p. 18). It was these two interests - science and fishing - that merged to transform not only Armstrong's life but the life of a whole nation.

Armorer Donkin was the senior partner in a highly successful legal practice whose clients included many of the principal families in the region. Thus, William Armstrong seized the proffered opportunity to article his son to Donkin's firm. With no positive alternative plans in view, the youth had little choice than to become a junior in the business. When Donkin eventually died, William George inherited his considerable fortune. Armstrong worked in Donkin's chambers for about four years before going to London for further tuition with the firm of his late sister's husband who was a special pleader at the Temple. Ann Armstrong, eight years her brother's senior, had married William Henry Watson in 1826, when she was 24 years old. Two years later, she died, a few months after giving birth to her only child, John William. (Dougan, p. 25). In 1833, Armstrong returned to Newcastle, and in 1835, at the age of 25, he became a partner in the firm which now became known as Donkin, Stable and Armstrong. With a settled career in view, Armstrong married Margaret Ramshaw the following year.

Although Armstrong entered the legal profession without demur, the law was not his main interest. Indeed he acknowledged that: "the law was not of my own choosing; my vocation was chosen for me, and for a good many years I stuck to it while all my leisure time was given to mechanics". (Quoted in Dougan, p. 26). This is endorsed by his biographer, Alfred Cochrane, who married the daughter of Sir Andrew Noble, Armstrong's astute confederate in later years. 'Every possible liberty seems to have been allowed him to follow his own scientific researches'. Furthermore, Cochrane claims that Armstrong's contacts with the influential and wealthy businessmen of the locality eased his path into his own business. (A. Cochrane, <u>The Early History of Elswick</u>, 1909, p. 19).

Armstrong considered his time spent in legal practice as "the waste of some ten or eleven of the best years of my life", yet he acknowledged, in retrospect, that this training was of inestimable value in his later business life. At first he had no wish to abandon the law, and, apparently, fulfilled all the duties assigned to him. Nevertheless, he confessed to being "an amateur scientist, constantly experimenting and studying in my leisure time". (Quoted in Dougan pp. 26-27.)

It was during these years as a solicitor that Armstrong effectively served his time as an engineer, for he made almost daily visits to the works in High Bridge, Newcastle, of Mr Henry Watson. Here he extended his knowledge and skill in mechanics as he watched the manufacture of turret clocks, telescopes and theodolytes for which the firm was renowned. Here, too, he established friendships not only with the owner, and his assistant, Mr. Hutchinson, but, more notably, with their sons. While he was developing these contacts, Armstrong's leisure pursuits of fishing and mechanics finally came together -a coincidence which was to alter his life and, ultimately, to bring fame and prosperity to himself and to Tyneside.

When Armstrong, Percy and Stephenson first embarked on their respective careers, the stability of the nation still rested on a social structure which maintained the dominance of an élite and the subordination of the lower orders. The Reform Act had only just been passed, and the House of Commons had, reluctantly, voted money for educational purposes. Another forty years would pass before elementary education would be made compulsory, and a new century would dawn before secondary education for the working classes was contemplated, or before higher education could become even a remote possibility for all but a limited few. For his part, Robert Stephenson would have limited the workers' education to mere vocational training, whereas Algernon George Percy supported their initiatives and promoted their educational opportunities. In the continuing debate during these momentous years, where did Armstrong stand?

CHAPTER II.

THE DEVELOPMENT OF INDUSTRY ON TYNESIDE, AND SOME DETERMINANTS OF ARMSTRONG'S CAREER.

Growing up in Newcastle, in the aftermath of the Napoleonic War, how far was the region's economic and industrial base conducive to the flowering of Armstrong's inventive genius?

From his earliest schooldays, Armstrong would see signs of the region's nascent industrial base, now so familiar to modern eyes. From Newburn to the mouth of the river, there were not only collieries but factories, foundries, shipyards, chemical works, salt pans and glass works. Remarkably, at that time, the Newcastle glass trade was second in importance to its coal. (Middlebrook, p. 141). Many of these industries owed their origins to Elizabeth I's policy of encouraging skilled Europeans to settle in England. Huguenots and Italians taught glass-making, while Germans taught paper-making, salt-making and cannon-founding - all of which arts, in due course, were established on Tyneside. In fact, it has been described as 'the Florence of the Industrial Revolution'. (A.E. Smailes, "The Development of the Northumberland and Durham Coalfield", The Scottish Geographical Magazine, Vol. 51, No. 4, July 1935, p. 201).

From the Middle Ages onwards, the coal trade provided Tynesiders with their livelihood through work in the collieries themselves or the ancilliary trades and servicing industries. Organising and controlling this complex situation of extraction and distribution were the Hostmen of Newcastle. Their name was derived from the medieval practice of

"hosting" whereby a merchant strange to the town was accommodated and given the necessary introductions to traders with whom he might wish to deal. They were incorporated in 1600 by Queen Elizabeth I as the Company of Hostmen authorised to have an exclusive right to trade on the Tyne in sea coal and grindstones. Membership was drawn largely from the Company of Merchant Adventurers, and their control of the trade on the Tyne gave Newcastle a monopoly of coal shipments in England when shipping was the cheapest form of bulk transport.
(F.W. Dendy, Ed. "Extracts from the Records of the Company of Hostmen of Newcastle upon Tyne." The Publications of the Surtees Society. Vol. CV, 1901, p. iii).

By 1615, a growing timber shortage in England resulted in legislation forbidding the use of wood as fuel in glass-works, at a time when glass production was mainly concentrated in the hands of French Huguenot immigrant workers, whose specialities were window glass and tall narrow beakers and bottles. In the event, Tyneside with its ample coal reserves and good sea communications seemed an obvious manufacturing centre, although, at first, Newcastle's 'sea coal' was considered to be too sulphurous for this purpose. (Ursula Ridley, "The History of Glass Making on the Tyne and Wear", Archaeologia Aeliana, 4th Series, Vol. XL, 1962, p. 146).

By 1623, Sir Robert Mansell had established a glass works in Newcastle at the confluence of the Ouseburn and the Tyne, and had been granted the monopoly for English glass manufacture. This privilege was maintained until the outbreak of the Civil War. (Ridley, p.18). Newcastle's pride in her local product is apparent in the seventeenth century merchants' houses on the Sandhill, still extant, with glass frontages on four storeys. (C.M. Fraser and K. Emsley, Tyneside, 1973,

p. 35).

At their zenith, the Tyneside glass works were located on both banks of the river, from its mouth - ten miles to the east of the town - to Lemington, four miles to the west. Distribution was done by way of the London collier fleet, wherein crates of glass were packed among the coal to prevent movements in the ship's hold with the consequent risk of breakages. (Fraser and Emsley p. 34).

Along the banks of the Ouseburn, in addition to the glass-houses and a lead works, there were a number of factories making soap, dry colours, and pottery. Here, too, a new chemical industry was founded by William Losh and his partners, who began making soda at Walker in 1796. Two decades later, copperas was being manufactured at Felling; coal-tar, sal ammoniac and prussiate of iron were being manufactured at Heworth, while oil of vitriol was being produced at Bill Quay and Walker. (Middlebrook, p. 141).

Within about a mile and a half from Armstrong's school at Whickham, near Gateshead, were the ironworks of Sir Ambrose Crowley, established in 1691. (Fraser and Emsley, p. 59). Crowley, a Quaker nail-maker from Stourbridge in Worcestershire, built his own community beside the Derwent, a tributary of the Tyne, whose waters were particularly suited to the tempering of steel, and where coal supplies were readily available. (P.M. Horsley, <u>Eighteenth Century Newcastle</u>, 1971, p. 56). Here, in 1690, he leased a disused cornmill and some land at Winlaton, which then consisted of a few deserted cottages. (Wm. Bourn, <u>History of the Parish of Ryton</u>, 1896, p. 117). This location enabled Crowley to expand his business to include hinges, wheel-hubs, chains, anchors and, finally, cannon. (Fraser and Emsley, p. 59). The anchors, being hand forged with sledge hammers, were reckoned to be the best in

England at a time when the demands of the Navy brought useful contracts to iron-manufacturers and encouraged speedier production methods, especially between 1685 and 1760, when its tonnage almost trebled in size. (E.J. Hobsbawm, Industry and Empire, 1977, p. 50).

The firm was completely self sufficient, both socially and industrially. Not only did Crowley build houses for the workers, but he also set up schools for their children. Indeed, in their social organisation, the works were, in many ways, as exemplary as Robert Owen's factory at New Lanark a century later, and make interesting comparison with Armstrong's eventual developments at Elswick.

In view of Armstrong's later concern with hydraulics and with mechanisation generally, it is interesting to note Arthur Young's observations when he toured Crowley's works during a visit to the North East shortly before 1768. (A. Young, A Six Months' Tour through the North of England, 1771, pp. 9-10). He praised the water powered machines used in production, but he deplored the continuing emphasis on manual skills, especially in the hand forging of anchors, which, he averred, could easily have been mechanised. Apparently, his criticism met with opposition, for, in a remark worthy of Armstrong himself, he observed that: 'There are no impossibilities in mechanics'. (Young, p. 11).

In noting this obsession with outmoded methods of production and the fact that their business, for some time past, 'has not been equal to what it was in the war', Young highlighted the problems which were to beset the region for generations to come, and with which Armstrong's own firm would, eventually, be all too familiar, namely, prosperity in war, recession in peace and a reluctance to adapt to 'to-morrow's technology'.

Another ironworks with which the young Armstrong would be familiar was that of Hawks and Company of Gateshead, begun in 1747. Like Crowley, Hawks started making anchors, chains and similar articles which were increasingly required with the expansion of shipping on the river. From these modest beginnings, he created one of the North's biggest iron industries and won large Government contracts for armaments during the Napoleonic War (Middlebrook, p. 141), thereby establishing a tradition which Armstrong himself was to continue with great success.

The Tyne, then, to the schoolboy William Armstrong, was a bustling and exciting place, with a multiplicity of industries along its banks. Here, too, were extensive roperies and ship-repair yards, while from Newcastle to Shields, there were docks to accommodate innumerable tall masted ships and men o' war, riding at anchor.

In the context of Armstrong's later career, the most relevant feature of all these industries was their total dependence on craft skills. Scientific method and its attendant educational requirements were matters of future concern both for the country and for Armstrong.

Nevertheless, it was no uncouth, industrial wilderness in which he grew up. Already, albeit imperceptibly, Newcastle was beginning to emerge as the Northern metropolis she was destined to become. From the eighteenth century onwards, the town gradually shook itself free from the strictures of its town walls and merchant controlled municipal administration. The days when it was the last outpost of the Roman Empire - a frontier town, occupied by a transient and alien population - were now far gone. A spirit of improvement was in the air, as seen in the general movement for political, social and intellectual reform which, in Newcastle, was activated mainly by the rising middle class, attracted to the area by its developing industrial and commercial interests. Many members of this group were associated with the town's churches, especially the new Unitarian Chapel in Hanover Square, with its young, dynamic minister, the Rev. William Turner. In addition, groups of radicals, scientists and business people, including William Armstrong, senior, were actively supporting the new learned societies, like the Literary and Philosophical Society, where they could discuss the important issues of the day.

More tangible proof of the influence of these people of taste, affluence and status was seen in their growing interest in the Arts and in their adoption of the classical style of architecture in the new town centre. The more ambitious schemes of Grainger, Dobson and Clayton extended the town beyond its medieval walls, till it eventually stretched from the Central Station - on the line of Hadrian's Wall and his original fort - to the Haymarket. When complete, it was, according to Pevsner, 'the best designed Victorian town in England'. (L. Wilkes and G. Dodds, Tyneside Classical, 1964, p. 81).

The deepening appreciation of the Arts in general is evident in the continuing popularity of the town's subscription concerts, which were inaugurated as early as 1736 by the local composer, Charles Avison. In addition, among the best known of Newcastle's artistically gifted population, Thomas Bewick - Ralph Beilby's pupil - is still acknowledged as the master of English wood engraving. Then there were the glass-blowers who produced rare crystal which was exquisitely decorated with engraving by John and Samuel Challinge, or with enamel by William and Mary Beilby. Besides, the Newcastle Assay Office, which was re-established in 1702, had no fewer than 78 silversmiths registered, with their marks, and is credited with having passed an average of 12, 500 ounces of silver every year at that time. (Fraser and Emsley, p. 58).

In light of this evidence, it would seem that Armstrong's formative years were spent in a locality which boasted not only an established industrial and commercial base with a highly skilled and dedicated workforce, but also people of influence, affluence and discernment, who demanded the best that money could buy, in whatever sphere they chose to operate.

Contact with people of this class and culture enabled Armstrong not only to embark on a legal career with the firm of Armorer Donkin, but to move easily among the business and professional people with whom he came in daily contact. On completing his apprenticeship in Newcastle, he went to London to further his legal training under the tutelage of his brother in law William Henry Watson who was a special pleader in Lincoln's Inn. (Welford, Vol. III p. 577).

By the time Armstrong returned to Newcastle in 1833, a number of educational initiatives had taken place which were to have a bearing on his future career as an industrialist. What was the extent of such initiatives, especially in scientific education, and what was the nature of Armstrong's response?

Arguably, the three most noteworthy events, in this context, were the development of the Mechanics' Institutes, including that of London; the founding of a non-sectarian college, in 1828, in opposition to Oxford and Cambridge, which, in 1836, became University College, London, (Derek Beales, <u>From Castlereagh to Gladstone, 1815 - 1885,</u> 1969, p. 68); and the establishment of Durham University in 1832. (C.E. Whiting, <u>The University of Durham, 1832 - 1932,</u> 1932, pp. 41-42).

There is no evidence to suggest that during Armstrong's stay in London he took the opportunity to study educational issues other than those germane to his legal career. Nevertheless, in view of his later involvement in engineering and scientific education, it would have been in his own best interests to have made a deeper study of such developments in the capital, especially those of the London Mechanics' Institute and University College. Had he done so, the development of the Elswick Mechanics' Institute and of the Newcastle College of Physical Science might have been expedited.

With Henry Brougham as its driving force and Dr George Birkbeck as its President, the London Mechanics' Institute opened in 1824, with the stated aim of instructing its members 'in the Arts they practise, and in other branches of scientific and useful knowledge'. (J.G. Godard, George Birkbeck, Pioneer of Popular Education, 1884, p. 55). During the first year, lectures were given, not only in mathematics, chemistry, geometry, hydrostatics, astronomy and electricity, but also in French language. (M. Tylecote, The Mechanics' Institutes of Lancashire and Yorkshire before 1851, 1957, p. 19).

By the time Armstrong arrived in London, the Mechanics' Institute was firmly established, and Brougham had already turned to another educational project which, consequential upon the growth of physical science, was to have important implications for Newcastle when Armstrong was internationally renowned. This was the founding of a college in Gower Street, London, exempt from religious tests, which was to present a challenge to the prevailing educational order.

By this time, the English universities had become, in effect, finishing schools for the upper classes, whose fees alone restricted educational opportunity to the nobility and wealthier gentry. (H. Hale Bellot, University College, London, 1826 - 1926, 1929, p. 5). Not that England was intellectually dormant before the nineteenth century, indeed there was a wide proliferation of learned societies in the country as a whole.

In London, the Inns of Court, of which Armstrong himself was a member, dated from medieval times; the Royal Society was established in 1660; the Royal Institution in 1779; while in the provinces, associations like the Literary and Philosophical Societies of Manchester and Newcastle, and the Lunar Society of Birmingham, became centres of scientific discussion and enquiry for the aspiring middle classes of the day. In addition, the Dissenting Academies continued to provide education, including science and mathematics, to university level and in the larger provincial cities, like Newcastle, medical schools began to emerge from the 1820s. (B. Simon, The Two Nations and the Educational Structure, 1780 - 1870, 1974, p. 119). Nevertheless, none of these agencies awarded degrees, and no effective challenge to Oxford and Cambridge emerged until, in 1826, a group of people headed by Brougham and Thomas Campbell, the poet, sought to establish a "University of London", later to become University College, London, not by Charter, but by a joint stock enterprise. (James Mountford, British Universities, 1966, p. 15).

Those supporters of the scheme who had been educated in Scotland had clear ideas about the characteristics of their proposed institution. Primarily, it was to be non-residential, thereby circumventing the vexed question of religious education, (Bellot, p. 55), while the moderate fees were aimed at attracting the 'middling rich' and those 'with comfortable trading fortunes'. (The Times, 9th February, 1825). Another characteristic was its modern curriculum. Instead of the classics of the ancient universities, its studies were to include physical science, medicine, modern languages, law, politics, economics and history. Furthermore, the tutorial system of Oxford and Cambridge was to be replaced by the professorial system, with lectures. The curriculum was to be flexible, and the students were free to attend lectures in the subjects of their choice. (Bellot, p. 10). Although its founders looked mainly to Edinburgh, London was thereafter to be the example for those who promoted similar schemes in later years. Indeed, how far did Armstrong and the founders of the College of Physical Science in Newcastle take this as their prototype? But that is anticipating events.

Meanwhile, from the outset, the new institution was meant to provide higher education for students unable to go to Oxford or Cambridge, and to include the study of subjects hitherto neglected by the ancient universities. At first, there were doubts about its name, and if it should grant degrees. Not surprisingly, attacks soon came from two influential sections of the Establishment. Oxford and Cambridge successfully resisted the granting of its charter, while the Anglicans objected to what Thomas Arnold described as 'that godless institution in Gower Street'. In consequence, the rector of Lambeth proposed the establishment of another collegiate institution in London in which religion was to play an essential part. (F.J.C. Hearnshaw, The Centenary History of King's College, London, 1929, p. 35). A public meeting was held on the 21st June, 1828, at which it was agreed to found a new college based on the doctrine of the Church of England. With King George IV as its Patron and the Archbishop of Canterbury as its Visitor, it became known as King's College, and opened in the Strand in October 1831. (Hearnshaw, pp. 39, 65 and 78).

As a result, London now had two colleges supported by rival political parties and subscribing to different ideals. The first was supported by the Whigs and the Nonconformists, but was unchartered, while the second, supported as it was by the Tories and the Anglicans, was under Royal patronage, yet neither was empowered to grant degrees. In an endeavour to resolve this impasse, a merger was proposed but rejected by King's College. Meanwhile, the advent of the Whigs to power encouraged the older institution to renew its petition for a charter, which was granted in 1836. At the same time, a compromise was reached, and the University of London was created with the power to award degrees in Arts, Law and Medicine. The college hitherto known as 'London University' now became University College, London, while King's College retained its original title.

Among distinguished Northerners connected with London University, in the last century, were Hugh, the third Duke of Northumberland, who was appointed a life governor of the newly opened King's College, (Hearnshaw p. 71), and Robert Spence Watson who graduated from University College, (Bellot, p. 293), and whose efforts to promote the Newcastle College of Physical Science, later Armstrong College, Durham University, will be noted in due course.

Meanwhile, another important development had taken place before Armstrong returned to Newcastle. This was the founding, in 1832, of Durham University. Although this was the first attempt to come to fruition, over the centuries there had been other schemes aimed at connecting Durham Cathedral with higher education. Among the more successful was the monastic foundation which became University College, Oxford, with which the modern University of Durham can claim some historic link. (J.T. Fowler, Durham University, 1904, p. 1).

No other centres of learning, comparable with those of Oxford and Cambridge existed in England at that time, therefore it is remarkable that several petitions proposing universities in the North were ignored until after the Civil War. The period of the Commonwealth was singularly conducive to the advancement of learning, with men like Hartlib and Boyle leading the way. Reform, especially in education, was strongly advocated, and new ideas were accepted according to their contribution to the public good. (J.J. O'Brien, "Commonwealth Schemes for the Advancement of Learning", B.J.E.S. Vol. XVI, February to October 1968, p. 42).

Cromwell himself was known to favour Durham as a suitable location for the establishment of a new college and a deputation went from the city to meet him in Edinburgh in 1651. Unfortunately, owing to more immediate business, the matter was deferred until 1656, when the Privy Council appointed a committee, including Samuel Hartlib, to prepare the statutes of 'the College in Durham of the Foundation of Oliver, Lord Protector'. (G.H. Turnbull, "Oliver Cromwell's College at Durham", Durham Research Review, No.3 September 1952, p. 1). Among other recommendations was the establishment of a 'Mechanical Schoole, a College of Science, along with several Schooles, a library and a worke-house in Durham'. Had this plan materialised, it would have anticipated, by more than 200 years, the establishment of the College of Physical Science in Newcastle.

In May 1657, the constitution was prepared for a college to be established within the precincts of the Cathedral and the Castle but no reference was made to university powers. Indeed, in its original form, Durham was not intended to rival Oxford and Cambridge, but was to be an independent college, like Eton and Winchester. (Fowler, p. 20). At the end of 1658, the College petitioned Richard Cromwell for university status. This was opposed by Oxford and Cambridge, but before a settlement was reached, the Monarchy had been restored, and the matter was left in abeyance.

No further initiative was taken until after the establishment of King's College, London. The Anglicans turned their attention to Durham, especially when the radical ideas of the time culminated in the Reform Bill and threatened the status quo. (Mountford, p. 17). Thus, fearful lest the new legislation might force ecclesiastical funds to be diverted to secular use, the Durham hierarchy decided to divert part of their revenue in order to establish a university. (Beales, p. 124).

Possible opposition from nonconformists and reformers caused the Bishop of Durham, William Van Mildert, to advocate silence on the university scheme until it was well advanced, for fear of 'any mongrel affair at Newcastle, (and of) any fierce attack upon Church dignitaries in the House of Commons'. (Whiting, p. 33). The first scheme was then outlined. Under the Bishop as Visitor, the Dean and Chapter were to be the directing body. In addition to a Principal and a Tutor, who might also be Vice Principal, there were to be Professors of Theology, Classics, Mathematics, Modern Languages, History, Natural Science and Philosophy, with provision for the later appointment of Readers. Initially, there would be 20 scholars and 20 fee-paying students. (Whiting, p. 33).

On the 28th September, 1831, the Chapter resolved unanimously that a university should be established and plans were prepared for the passage of a bill through Parliament. Bishop Van Mildert had insisted that nothing short of a university, with the power to grant degrees, would satisfy either the northern public or the local gentry, who would refuse to send their sons to a mere college. (Whiting, p. 39). Fortunately, among the local aristocracy, both the Duke of Northumberland and Earl Grey gave their unqualified approval, while Lord Durham did not oppose the motion, although he desired further clarification on some points.

Admission to the university was to follow the Cambridge example whereby religious tests applied only on graduation. This annoyed the Newcastle Dissenters who petitioned the House of Commons to allow all denominations to enjoy the full privileges of the university without religious tests. However, after further debate, it was agreed that as the money involved belonged to the Anglican Church, outside bodies were powerless to dictate their terms. The opposition withdrew, and on the 4th July, 1832, the Royal assent was given, enabling 'the Dean and Chapter of Durham to appropriate part of the property of their church to the establishment of a university in connection therewith'. (Whiting pp. 41-42).

From the outset, the university was to have a residential system similar to that of Oxford and Cambridge. Accommodation was provided originally in the house on Palace Green known as the Archdeacon's Inn, to which the first students came in October 1833, but in 1837, the Bishop of Durham, through an Order in Council, allowed the university to appropriate Durham Castle, one of the palaces of the Palatinate, for its use. (John C. Dewdney, Durham County and City with Teesside, 1970, p. 497).

In view of Armstrong's later concern with engineering and scientific studies, it is appropriate to note that, as early as 1838, the first course of its kind in the country was begun at Durham University in civil and mining engineering. (Whiting, p. 80). The University staff responsible for its establishment included the Rev. Temple Chevallier, Professor of Mathematics, the Rev. Charles Whitley, Reader in Natural Philosophy, and the newly appointed lecturer in chemistry and mineralogy, James Finlay Weir Johnston, a Glasgow graduate, who had recently returned from Europe. Here, he visited, among others, the Swedish chemist Berzelius, and the Danish Ørsted, who discovered the magnetic effect of electric current, a subject in which Armstrong was to display such interest, and on which he was soon to lecture in Newcastle. On his return to England, Johnston became involved with the foundation of the British Association for the Advancement of Science, and, helped by his colleagues in Edinburgh, recorded its first meeting in York in September 1831. (G.R. Batho, "A Man of Science: James Finlay Weir Johnston, 1796 - 1855". History of Education Society Occasional Publication, No. 5, 1980, pp. 23-24 passim).

Johnston returned to Sweden in 1832, to work in Berzelius' laboratory, whence he took up his appointment at Durham University. Although he is credited with lecturing in a variety of subjects, including general and applied chemistry, mineralogy and geology, the demands of his post were not unduly excessive and afforded ample opportunity for lecturing elsewhere. The Literary and Philosophical Society of Newcastle upon Tyne invited him to contribute to their regular programme of subscription lectures, aimed at fostering the advancement of scientific knowledge. This programme is described in detail in the next chapter, but it is noteworthy that Johnston's chemistry lectures were so popular that the proceeds paid for a similar course the following year. (Batho, p.24). Although, at the time of Johnston's appointment to Durham, the current academic research was seldom relevant to the industrialists who still relied on 'mechanical instinct' for much of their success, nevertheless, there were three areas where the theorist and practitioner had successfully bridged the gap. These were in medicine, in chemistry and in the invention of the steam engine. (Checkland, p. 74). While the conflict between theory and practice continued, a group of scientists based in Edinburgh, led by Sir David Brewster, and including Johnston, spearheaded the movement which led to the establishment, in 1831, of the British Association for the Advancement of Science. (C. Preece, "The Durham Engineer Students of 1838", Proceedings of the Institution of Electrical Engineers, History of Engineering Weekend Meeting, 6th - 8th July, 1979, p. 3). As the traditional attitudes to engineering education continued to be questioned, Johnston and his colleagues decided to devise an appropriate course. To that end, he helped to establish the Durham University course in engineering. Not only was this considered to be Johnston's greatest contribution to Durham University itself, but to industrial education in general. (Batho, p. 24). Hitherto, Civil and Mining Engineers owed their training more to the artisan and the craftsman than to the academic, but now, for the first time in history, the engineer was to have parity of esteem with other professions. As the University of Durham Calendar for 1839 notes: 'If an education of this nature were carried on in the same place and in the same spirit with a more general course of academical reading, great benefit might be anticipated from the association of young men intended for the higher departments of civil engineering with those who were destined for the learned professions, or for other stations in the higher or middle ranks of life'. (Quoted in Batho, p. 25). Thus, the Civil Engineers, being admitted to the University, were subject in all respects to the same rules and privileges as other students.

In view of Armstrong's own involvement in engineering education and in the later developments in Newcastle, further details of this course are necessary. Admission to the three year course was made on the basis of success in Latin, arithmetic and the elements of mathematics. The curriculum itself, drawn up by Chevallier, Whitley and Johnston, consisted of both the theoretical and practical studies associated with civil and mining engineering. Institutional laboratories were not common in nineteenth century England, yet Durham had some of the earliest scientific laboratories on record, and Johnston's science classes made full use of these facilities. (Preece, p. 5). Other subjects included dynamics, hydrostatics and hydraulics, as well as studies of the steam engine, optical instruments, theoretical and practical chemistry, theory of heat, mineralogy, geology and metallurgy. An experienced Civil Engineer gave instruction in the practical classes which included surveying, levelling, mapping and architectural drawing. Furthermore, the engineering students attended classes in modern languages, the first students in the University to do so. (Preece, p. 7).

The first final examination papers were set in 1840 and were both internally and externally assessed. The University, realising the status of the course within the engineering profession, were at pains to engage engineers of high standing as examiners. Over the years the distinguished list included not only national figures like Sir John Rennie and James Walker, the President of the Institution of Civil Engineers, but local men, whose names recur in this study, like Nicholas Wood, the first President of the North of England Institute of Mining Engineers, and John Buddle, the local colliery viewer and mining engineer, as well as Thomas Sopwith, the Newcastle engineer and surveyor who not only had close associations with the mining industry, but who was a personal friend of both Robert Stephenson and William George Armstrong. (Preece, p. 9.).

Despite these distinguished examiners and the academic rigours of the course, the students were not awarded a degree, but the Academical Rank of Civil Engineer, which was deemed to be 'degree equivalent'. As such, it was treated in all respects as a degree, and it was awarded in Congregation with the B.A. degrees, when the engineers wore their own distinctive academic dress, and were, thereafter, entitled to use the letters C.E. after their names. (Preece, p. 6). Although most of their contemporaries at Durham were described as 'sons of gentlemen', many of the engineering students came from less affluent families and had to finance their studies by teaching or other employment. These students were further penalised by the high cost of the course, which in some cases was almost double that for a student in Arts.

Nevertheless, recruitment to the course was so good that, by 1840, there were more students registered for engineering than for Theology. Indeed, Preece suggests that, given a continuation of this success, Durham could have become the first technological university. (Preece, p. 10). In the event, the high cost of tuition fees; the lack of universal recognition of the Durham qualification, and the need for the students to complete a full engineering apprenticeship, despite three years' attendance at university, caused a rapid decline in numbers, until 1851 when no further students were registered on the course. However, when the Great Exhibition of 1851 aroused a renewed interest in engineering and scientific studies, Durham once more rose to the challenge. A new course was planned, in which Thomas Sopwith was closely involved, which comprised two years of academic study combined with industrial experience. Unfortunately, these proposals were too visionary for their time, and, although students were admitted in 1858, the course, like its predecessor, was doomed to failure. This was the last attempt to establish an engineering course at Durham until the modern Department of Engineering Science was founded in 1965. (Preece, p. 11). When, eventually, the College of Physical Science was established at Newcastle upon Tyne in 1871, in which Armstrong and the North's leading industrialists had a vested interest, all the science teaching of Durham University was transferred there.

Meanwhile not only the engineering courses at Durham, but the

University itself was under threat of closure, when, in 1861, only 19 degrees and licenses were conferred. (Whiting, p. 97). Predictably, when these returns were laid before Parliament, a Royal Commission was appointed to enquire into the conditions and prospects of the University and to make recommendations for its improvement. Among the witnesses who gave evidence in 1862, were Armstrong's fellow industrialist, Isaac Lowthian Bell, and Nicholas Wood, President of the North of England Institute of Mining Engineers. When Bell's opinion was sought on the state of scientific education in the University, he replied that he was at a loss to understand why it had failed, especially in view of the 'considerable demand for an education of that kind'. When further pressed on the issue, he suggested that: 'the class of chemistry, when in existence, Dr. Johnston's class, was not a very successful one, even at Durham', and wondered 'whether it was owing to some peculiarity of the doctor himself, or owing to the town of Durham not being very conveniently situated'. (Report of the Commissioners Appointed for the Purpose of the University of Durham Act, 1861, Minutes of Evidence, paragraphs 1823-1824). He then made a strong bid for the location of such classes in Newcastle - a case which will be detailed in a later chapter.

It has been suggested that the location of Durham was a more credible reason for the failure of the science classes than any inadequacy in Johnston's work, especially in light of Robert Spence Watson's later tribute that: 'he was a man of striking ability and his work in the district is not forgotten'. (Quoted in Batho, pp. 24 - 25 passim). Indeed, his name is immortalised in the Johnston Chemical Laboratory in the original Armstrong College, now the Armstrong Building of Newcastle University. (Whiting, p. 81).

Further evidence of the decline in science at Durham is seen during the tenure of Thomas Richardson, the Newcastle born chemist who studied in Glasgow and at Giessen. (M.S. Byrne, "Thomas Richardson: His Contribution to Chemical Education", <u>Durham Research Review</u>, Vol. 7, No. 33, p. 944). Despite Richardson's ability and his contributions to the British Association's meetings of 1838 and 1839, after he was appointed to succeed Johnston at Durham, in 1855, he 'had no class, but gave an annual course of public lectures'. (Whiting, p. 102). Following the publication of the Royal Commissioners' Report; the decline in the number of students on science courses; the failure of the second engineering course, and the death of Dr Richardson, in 1867, the way was open for the establishment of a College of Physical Science in Newcastle. (Whiting, p. 117). Thereafter, the reputation of the University at Durham rested almost entirely on the excellence of its School of Theology. A very high proportion of its graduates entered the Church or the teaching profession, while science and research disappeared almost completely. (Dewdney, p. 498). This situation was to be the cause of deep concern and protracted debate among northern industrialists - not least to Armstrong himself.

Meanwhile, after his stay in London, Armstrong returned to Newcastle in 1833 and became a partner in the legal firm thereafter known as Donkin, Stable and Armstrong. Apart from the national and regional developments in scientific education already noted, what comparable initiatives existed in Armstrong's native region at that time? In addition to the University of Durham, Newcastle itself had a flourishing Literary and Philosophical Society, a Mechanics' Institute, and a School of Medicine and Surgery, while plans for a College of Science, supported by members of the region's scientific and industrial community, were already being formulated.

Nonetheless, in view of all these educational developments in science and engineering, and, moreover, in light of his father's mathematical acumen and active involvement with the local scientific community through the Newcastle Literary and Philosophical Society, why did the younger Armstrong evince so little interest in such matters at this stage in his career? Had he done so, especially with his influential family connections, would this have expedited the plans for the College of Science in Newcastle, proposed by Dr T. M. Greenhow in 1832? As it was, that event had to await a new generation, with different needs and aspirations, for its fulfilment, by which time Armstrong was no longer the unknown junior partner in a legal firm on Tyneside, but a world leader in armaments and a titled man of considerable influence and fortune.

CHAPTER III.

THE SCIENTIFIC COMMUNITY IN NEWCASTLE FROM 1832 TO 1848.

If Armstrong paid scant attention to the educational developments already described, at what stage in his career did he become involved in those of his native Tyneside?

As Newcastle emerged from behind her medieval town walls, to become the centre of one of the country's foremost industrial areas, the developments of the time, with their increasing dependence on scientific principles, began to challenge the existing educational provision of the region. Robert Spence Watson argued that: 'There is sufficient (evidence) to show us that Newcastle was one of the first places to feel the stirrings of that new spirit of patient inquiry and investigation which was to revolutionise the whole scheme of education'. (Spence Watson, p. 208). This evokes several questions on the nature and substance of this phenomenon in the context of Newcastle generally and of Armstrong in particular.

Assuming the validity of Spence Watson's comment and mindful of Armstrong's later concern, was there an identifiable body which could be described as 'the scientific community' in Newcastle? If so, had it an institutional base; who were its leaders and what was the social composition of its membership? Moreover, what was the nature of its interest? Was it purely educational in concept, or had it charitable, social or economic overtones? Furthermore, were there local educational developments like those already noted elsewhere, and what was the nature and extent of Armstrong's involvement?

Essentially, Spence Watson's 'spirit of patient inquiry' was most apparent in the industrial areas of the region, and not least among the ambitious professional and middle classes of Newcastle, many of whom were attracted to the district by the developments of industry. These included not only those with commercial and business interests, but men of high ability from the medical fraternity, many of whom had graduated from Edinburgh. The opening of Newcastle's Infirmary and Dispensary, as well as the economic benefits of general practice, attracted men who, from its inception, became associated with the town's Literary and Philosophical Society, and formed the vanguard of an intellectual, and predominantly scientific, élite. Learned societies began to emerge to meet the demand for lectures on scientific and other popular subjects. Indeed, as early as 1802, the Annual Report of Newcastle's Literary and Philosophical Society recorded 'the numerous and punctual attendance lately given to the Lectures we have heard on that interesting Science, Chemistry'. Furthermore, the local heavy industries and the sea-borne trade, with its dependence on navigational skills, relied increasingly on mathematics, so it was fortuitous that the region produced, at that time, several mathematicians, like Dr Charles Hutton, whose knowledge was to benefit the country at large, (Horsley p.25), and William Armstrong, senior, whose valuable collection of books on the subject was to make such a notable addition to one of the town's best known libraries.

Charles Hutton, the son of a local colliery deputy overman, had first attended a dame school in Percy Street, Newcastle, before going to the school of a clergyman in Jesmond. Here, he acquired his life-long passion for mathematics, and after working for a time at Benton Colliery, he returned to take charge of his old school. (Horsley p. 44). Hutton continued his own studies by attending evening classes, before opening a larger school, in 1760, with an ambitious syllabus, including writing, arithmetic, algebra, geometry, trigonometry, conics and mechanics, together with their application to navigation, surveying, gunnery and astronomy. The school continued to flourish, and attracted many famous names, including John Scott and Bessie Surtees, the future Lord Chancellor, Eldon, and his wife. Such success necessitated the building of larger premises in Westgate Street, where he continued until 1773, when he was appointed Professor of Mathematics at Woolwich Military Academy. (Hans, p. 109).

Not only did he give private lessons in the homes of his pupils, but his school became the centre for public lectures. Here, Dr Caleb Rotherham, whose father was master of the Dissenting Academy at Kendal, lectured throughout its existence in geography, astronomy and natural philosophy. Indeed, from these beginnings, the Newcastle Literary and Philosophical Society emerged, with Rotherham as its first lecturer. (Hans, p. 148).

Hutton's school is noteworthy not only as evidence of the early emergence of a scientific community in Newcastle, but also as the school of John Howard, tutor to William Armstrong, senior. Howard had opened a school near Carlisle, which, because of his mathematical and scientific talents, drew him to the attention of the local Bishop. Through this patronage, Howard attended the city's Grammar School before going to college. (Mackenzie, p. 465). In 1780, he opened a school in Carlisle, itself, to which, after a brief stay in Ireland, he returned in 1786 to continue his mathematical teaching, before removing to Newcastle in 1794. Here, he became master of the mathematical school, in Hutton's former school-house. (Hans, p. 148). Although no firm evidence has been traced to substantiate this, in view of William Armstrong, senior's Cumbrian birth and family connections, it is reasonable to suppose that he actually attended Howard's school in Carlisle. In any case, Howard, on removing to Newcastle, immediately became involved in lecturing to the incipient Literary and Philosophical Society. Indeed, in the year after his arrival, he is reported to have read an essay on the construction of the common balance, while William Armstrong senior, described by Mackenzie as 'formerly his pupil' (Mackenzie, p. 465), lectured to the Society in 1797, on 'The Algorithms of Impossible or Imaginary Quantities'. Howard, who agreed with Armstrong senior's hypothesis, led the debate on the subject at a number of subsequent meetings. (Fifth Annual Report of Newcastle Literary and Philosophical Society. Published 1798). Thus, it would appear, that the two were certainly acquainted by the time of Armstrong senior's own arrival in Newcastle, if not before.

From these modest beginnings, a base for a scientific community was established in Newcastle. How did it operate? How was it organised? During the eighteenth century there had been a growing, national, interest in such intellectual activities as the giving of lectures, the holding of debates and the formation of discussion groups. As early as 1739, Isaac Thomson established a course in natural philosophy in Newcastle, (Hans, p.144), while another course of lectures was given by an astronomer in 1768, and a debating society - 'The Philosophical Society' - was formed in 1775, (Middlebrook, p. 154). Unfortunately, the subjects chosen for debate were too limited in appeal, and the membership never rose above twenty. Of more practical value, at least to the professional interests of its members, was the Philosophical and Medical Society, formed in 1786. Again, because of limited appeal, it had disappeared by 1800. Nevertheless, during its existence, it attracted men of such academic stature as Dr John Rotherham, who became its first President. (I. Inkster and J. Morrell, (Eds.) Metropolis and Province. Science in British Culture, 1780 - 1850. 1981, p. 209).

Perhaps the best known, and the most enduring of the societies formed at this time, was the Literary and Philosophical Society, founded in 1793 to promote a wider interest in literary and scientific subjects. This was to be the institutional base from which most of Newcastle's scientific community operated, and the seed bed from which developed many of the region's learned societies and educational institutions including the College of Physical Science. William Armstrong, senior, joined the Society in 1799, and took an active part in its management, while his son, whose membership dated from 1836, was to be its President for almost 40 years, in succession to Robert Stephenson. (Spence Watson, p. 321 and Appendix C). Thus, a deeper consideration of the Society's history and development is deemed appropriate.

The Society began on an informal basis during the winter of 1792 when a small group of people met in each other's houses to discuss topics of mutual concern. When a more formal basis for the group was required, the Rev. William Turner, of the Unitarian church in Hanover Square, Newcastle, was invited to lay down guidelines. His paper, 'Speculations on a Literary Society' was circulated, and discussed. At a meeting in the Assembly Rooms, on the 24th January, 1793, Turner observed that, at the time, London itself had only three learned societies, and the Literary and Philosophical Society of Manchester, inaugurated in 1781, was the only one of its kind in the country. (Spence Watson, p. 28). He urged the spread of such societies hoping that they would 'act as nurseries to the larger and more important institutions', and that they would 'diffuse more extensively a taste for philosophical and literary enquiries'. In his view, Newcastle offered a suitable venue for such an institution on several counts, notably the town's strategic position at the heart of an industrial region, whose problems increasingly called for solutions by theoretical, rather than practical, means.

The outcome was the formation of the Literary and Philosophical Society of Newcastle upon Tyne, whose committee was representative of the local civic, business and professional interests, including some of the staff of the Infirmary, founded in 1752, and the Dispensary, founded in 1777. Thus, from the outset, the Society represented the interests of the middle classes of the district. On the 7th February, 1793, a meeting was held in the Dispensary at which the Society was formally inaugurated, and Turner's main proposals were adopted.

Although the Society met a social as well as an educational need, its underlying thrust was economic. Indeed, from its inception, members unfailingly emphasised the Society's role in solving the industrial problems of the day. For instance, the switch from water to steam power as industry's main energy source increased the demand for coal, on which the region's economy was based. The resultant digging of deeper shafts posed problems of severe flooding in the mines. The question of safety in the mines and the need for fuel conservation was to become a recurring concern of local engineers, including Nicholas Wood and Armstrong, and proved to be a major factor in the establishment of the College of Physical Science in Newcastle. Meanwhile, the increased use of steam engines to pump away the flood water, combined with the need to transport coal quickly and cheaply, led to the eventual development of the locomotive, which, as noted earlier, resulted in the opening, in 1825, of the Stockton to Darlington Railway, mainly through local enterprise.

Despite an early problem of finding suitable premises, the Society had, by 1798, settled into the Old Assembly Rooms, in the Groat Market. Thereupon, Turner suggested that, in addition to its monthly meetings, with their wide appeal and social ethos, a regular course of lectures should be introduced, specifically aimed at furthering scientific knowledge. Thomas Bigge, one of the Society's Vice Presidents, made a keynote speech, as early as 1802, in which he stressed the urgent need for a wide-ranging provision of educational establishments, for all classes of society, based on 'the application of scientific principles to the process of trade and manufacture'. In emphasising that Newcastle's location was the strongest argument in favour of such institutions, he regretted that the siting of the Royal Institution and similar societies in the metropolis, and that of the Scottish Universities, limited their value to those who could easily attend them. Anticipating the development of similar institutions at local level, he averred that: 'The glory will belong to that community which forms them first'. (Spence Watson, p. 212).

Realising that Bigge's proposals were too visionary, both historically - during the protracted war with France- and economically, the Society did, nonetheless, concede 'their great importance to the interests of society at large, and of this district in particular'. To further this end, an open Committee was formed, whose findings ensured 'the establishment of a permanent Lectureship in the several branches of Natural and Experimental Philosophy and Chemistry'. The Rev. William Turner was chosen as Lecturer of the proposed institution, and Hugh, the second Duke of Northumberland, became its Patron, donating £200 towards the purchase of apparatus, and proposing the levying of an annual subscription towards its continuance. (Spence Watson, pp. 212 - 213). When the experiment was launched, in 1803, as 'The New

Institution for Permanent Lectures', this new section of the Society was to be self-supporting, through donations and fees from those attending the lectures. Turner continued as its Lecturer until 1833 when, aged 71, he resigned because he felt unable to keep pace with the latest scientific developments, especially in chemistry. During his term of office he lectured on a wide variety of subjects, including mechanics, hydrostatics and pneumatics, electricity and magnetism, chemistry, optics and astronomy. This was in addition to his main duties as minister of one of the town's largest churches and his active involvement in so many other issues of the time. Other lecturers at the 'New Institution' included J.F.W. Johnston of Durham University, who, in 1833, gave a course of 22 lectures and practical classes in chemistry, which proved to be extremely popular. (Batho, p. 24).

Meanwhile, the programme of monthly meetings continued. Although these have been described as 'the precursors of all the learned Societies in which (Newcastle) was to become so rich', (Spence Watson, p. 153), many were of specific application to the industries of the region. As early as 1796, it was proposed to establish a Mining Institute aimed at studying those problems peculiar to the mining industry. To this end, George Stephenson demonstrated his miners' safety lamp, in 1815. Because of his lack of communication skills, Stephenson was aided during the lecture by Turner and Nicholas Wood, the head viewer of Killingworth Colliery, under whom Robert Stephenson served his apprenticeship, (Rolt, p. 69), and who, later, promoted the North of England Institute of Mining Engineers. More significant in this context, however, were the lectures given at a later date by William George Armstrong, both on hydraulics and electricity, and by his friend, Joseph Wilson Swan, on his incandescent electric lamp.

Not surprisingly, the continuing expansion of the various programmes necessitated the purchase of new premises. By 1822, it was agreed to build a permanent home for the Society, at a cost below £4,000. The Building Committee included William Armstrong, senior, who by then was also a member of the General Committee, (Spence Watson, p. 73), while Armorer Donkin was listed among those whose 'public spirited measures' brought the project to fruition. (Spence Watson, p. 62). When a suitable site had been found, and the plans agreed, the foundation stone was laid by the Duke of Sussex, who was elected to the Presidency of the Royal Society in 1830. (Inkster and Morrell, p. 56). The new quarters, which the Society still occupies, were opened in 1825, on the site of the ancient town mansion of the Earls of Westmorland. (Charleton p. 136).

What had the Society achieved in over a quarter of a century? At that stage in its development, and in the absence of any local universities, it was, arguably, performing a function midway between the Dissenting Academies of its own time and the Extra Mural Studies Departments of to-day. Its permanent lecture programme was evidently aimed at the serious student, whose thirst for knowledge was not assuaged by any other agency, while the programme of monthly meetings performed a social as well as an educational function. Nevertheless, in line with the universities and other learned societies of the time, women were excluded from membership of the Society, although they were admitted as 'reading members' from 1798. In this connection, recent research suggests that Armstrong's mother, who was reputed to be a highly cultured woman, could have been one such member. (McKenzie, p. 11). Another criticism was the Society's over-riding pre-occupation with the needs of the middle classes. To some extent, the needs of the local working classes were being met through the Newcastle Mechanics'

Institute, in whose development individual members of the Literary and Philosophical Society played a notable part, but the criticism was valid.

A laudable characteristic of the Society, almost from its inception, was its fostering of other learned societies covering a wide range of subjects. One with which Armstrong would have been familiar from his earliest days was the Society of Antiquaries. Established in 1813, this was the oldest provincial antiquarian society in the country.

From the outset, the Literary and Philosophical Society made a collection of items aimed at the study of Natural History. This museum soon reached such extensive proportions that, by 1829, its presence was an embarrassment because there was insufficient room to display, adequately, its vast collection of geological and ornithological specimens. In consequence, many were permanently locked away and were, thus, of little value to serious students whose research would have been invaluable both to industry and society at large. At a meeting on the Society's premises on the 9th August, 1829, the Natural History Society was established. Its sponsors included, not only one of the region's chief landowners, Sir John Trevelyan of Wallington Hall, but - more notably in view of its future history - Albany Hancock. The new Natural History Society bought a site to the rear of the Literary and Philosophical Society and built its museum. Here it remained until 1884, when the North Eastern Railway Company purchased the premises for their extensions to the Central Station complex. A new site at Barras Bridge was chosen for the museum, which was known thereafter as the Hancock Museum, and to which the future Lord and Lady Armstrong were to be generous donors.

Meanwhile, what other learned societies had developed in Newcastle on Armstrong's return from London? One which, again, owed its origin to the Literary and Philosophical Society, was the North of England Society for the Promotion of the Fine Arts. At a monthly meeting of the parent society, held in September 1836, the idea was mooted by two members who despite other professional interests, were keenly interested in Fine Arts. These were Dr T. M. Greenhow, a local physician whose efforts to establish a College of Science will be noted in due course, and Thomas Sopwith the engineer and geologist, whose work at Durham University was described earlier. A further meeting was held a month later and the new society was inaugurated. Membership was to include not only painters sculptors and engravers, but engineers, architects and anyone interested in the Fine Arts. Apart from forming a library and holding regular exhibitions, the main aim was to form a School of Art which would include industrial design. Although the Society's original location was in Grainger's new Central Arcade, it later occupied rooms in the premises of the Natural History Society. The development by the Railway Company, in 1884, necessitated a move by what was then the School of Art, and which later became the Art Department in the Newcastle College of Science.

Although somewhat beyond the period under immediate discussion, it is appropriate to make a passing reference to the last, but, in the present context, one of the most noteworthy, of Newcastle's learned societies which developed from the Literary and Philosophical Society. This was the North of England Institute of Mining Engineers, organised by the region's mine owners, mining engineers and colliery viewers, following the Mines Inspection Act of 1852. Nicholas Wood was the first President and both he and other members of the Institute of Mining Engineers, including Armstrong, were eventually to play a notable part in the establishment of the College of Physical Science. Subsequently, most of the societies just described became part of the complex of the University of Newcastle upon Tyne. However, more immediate developments in scientific education, generally, had already taken place prior to Armstrong's return from London, and before the establishment of Durham University.

In Newcastle, as elsewhere, the middle classes were at the head of the movements for social reform engendered by the acceleration of industrial progress. Among the most notable of the leaders of the time were two members of the medical profession, Dr Thomas Greenhow and Dr (later Sir) John Fife. Why should the medical profession be so involved in social reform? A parallel at national level can be seen in the career of Dr James Kay, whose experiences as a medical student in the slums of Edinburgh and later among the cholera victims of Manchester, enabled him, as Sir James Kay-Shuttleworth, to lay the foundations of an effective national system of elementary education in England. So it was with Doctors Greenhow and Fife. Their professional experiences among the poor in Newcastle led them to seek educational solutions to many of the social problems of their day.

Meanwhile, what socio-medical reforms had taken place in Newcastle prior to 1832, which caused Greenhow to launch his campaign for a College of Science in the town? At national level, the fall in the mortality rate from 1750 was due partly to improved standards of public health and partly to improved medical knowledge. (Middlebrook, p. 122). This concern for better standards of public health led, in turn, to a social awareness of the need to establish infirmaries staffed by trained doctors and nurses, in conjunction with local dispensaries where even the poorest people could receive medical attention and advice. Although these movements began in London, they were soon emulated in other towns. As early as April 1751, a group of professional men launched a public subscription to build a General Infirmary in Newcastle. So great was the response that within a month they were able to receive patients in temporary premises in Gallowgate. Thereupon the Corporation offered a permanent site on the Forth Banks, at a nominal rent. Here, the precursor of Newcastle's eminent Royal Victoria Infirmary, to whose funds Armstrong was to contribute so handsomely, was opened on the 8th October, 1752.

Unfortunately, the prevailing attitudes of laissez-faire, which left the provision of medical and educational facilities to local initiative and voluntary philanthropy, prohibited further developments until 1822, when Dr John Fife opened a Hospital for Diseases of the Eye in Brunswick Place. Equally involved in this project, from its inception, was Dr Thomas Greenhow, already a prominent surgeon and active public figure in Newcastle. The son of a North Shields doctor, Greenhow trained at Edinburgh University and became a member of the Royal College of Surgeons in 1814. After serving as an assistant surgeon in the Army, he returned to Newcastle and joined Dr Fife in establishing the Eye Hospital. (Welford, Vol II. pp. 331-2).

Once established on Tyneside, Greenhow became a member of the Literary and Philosophical Society. It was at one of the Society's monthly meetings, in April 1831, prior to Armstrong's return from London, that he read a paper on 'The Expediency of Establishing in Newcastle an Academical Institution of the Nature of a College or University for the Promotion of Literature and Science, more especially among the Middle Classes of the Community'. Had his plan succeeded, Newcastle would have followed, immediately, London's lead in establishing an institution of higher education, free from religious tests, and would have pre-empted the Anglican initiative for a University in Durham. In the event, economic and religious constraints militated against it, and the matter rested for forty years, until another generation, including Armstrong, took up the cause.

In essence, Greenhow's proposals endorsed those of Thomas Bigge, in 1802. The latter, it will be recalled, envisaged the establishment of scientific institutions, not only for the education of the general public, in chemistry and other branches of natural philosophy, but specifically to meet local needs. Provision, he averred, should be made for both working men and the professional classes, to meet the new demands of their employment. In the traditional industries, he called for 'the systematic training of the younger mining pupils', while, in the emerging importance of Newcastle as a centre of medical excellence, he requested 'lectures on anatomy; on the principles and practice of surgery, and on the science of pharmacy', for medical students. Pleading the case for local scientific institutions, Bigge emphasised that: 'the miner, the manufacturer and the agriculturalist can rarely hope to participate in the advantages of experimental science unless they reside in the neighbourhood of a Philosophical Establishment', and stated, unequivocally, that: 'the town of Newcastle is singularly fitted to become the seat of (such an) Institution'. (Quoted in Spence Watson, p. 208 - 209).

In turn, the lecture which Greenhow gave, in 1831, encapsulated his life-long concern with scientific training at collegiate level for the youth of the developing industrial community of Tyneside. Through the press, through lectures and at public meetings, he waged a relentless campaign.

At the time, Greenhow's lecture to the Literary and Philosophical

Society was considered to be of such importance that it was ordered to be printed and circulated, not only among members, but among the wider public. (Spence Watson, p. 261). The main thrust of his argument was that, despite the outstanding attainments in science and industry, it was 'a remarkable fact that in no country in Europe are the means of obtaining a liberal and systematic course of academic instruction so sparingly supplied to youth as in England'. (T.M. Greenhow, Lecture read to the Literary and Philosophical Society of Newcastle upon Tyne, 5th April, 1831. p. 4). His second point reiterated the limited access to Oxford and Cambridge except for the wealthy, the members of the Church of England and those destined for a career in the Anglican priesthood, or the legal profession. His third argument endorsed the point advanced by the exponents of Durham University, namely, that remoteness from Oxford and Cambridge precluded many who could otherwise comply with their regulations.

He argued that the grammar schools were totally inadequate for the purpose because of their failure to meet the modern requirements in mathematics and science. (Greenhow, Lecture, p. 6). Having praised the developments in London which were 'free from some of the disadvantages of the older universities', he then ruled out that location on two counts - distance and morality. London, he claimed, was 'the last place where a prudent father would ----- entrust a youth from 16 to 18 or 19 years of age, ---- to his own guidance'. Moreover, having admitted his personal admiration for the Scottish universities, and noting that they were neither too distant nor too expensive, he argued that, apart from the schools of medicine, they were generally regarded by the English as local rather than national in character, and were 'not likely to be extensively resorted to by (them) for the purpose of general attainments only'.

Thus, having dismissed all the existing institutions, he made a bold plea for the establishment of a local college or university, based on the Scottish model. This institution, 'accessible to every youth in the middle walks of life', would offer instruction in the higher branches of mathematics, classical languages, literature and general science. Moreover, he claimed that the industrial developments then taking place, and the paucity of existing educational facilities, demanded the establishment of such institutions, not only on Tyneside, but in all parts of the country. Having, apparently, forecast the development of the civic universities later in the century, he further suggested that the timing of his proposal was propitious, because of the rise to power of the Whigs who favoured education not only for itself, but as a means of ensuring their party's political domination. (Greenhow, Lecture, p. 8).

Not surprisingly, he stressed Newcastle's claim as the most appropriate site for his proposed institution, on both specific and general grounds. The town, he maintained, was not only several hundred miles from London and the ancient universities, but was, in its own right, the natural metropolis of a large and prosperous industrial and commercial region. In consequence, here was a unique catchment area for the recruitment of students from the Northern counties alone.

He then listed the advantages of such an institution to the various professions of the region. The wealthy merchant, the juror and magistrate, the lawyer and the doctor would all benefit from an education, not only in classical languages, from which all scientific knowledge was derived, but from a training in logic and mathematical reasoning. Furthermore, he prophesied that the intended students would, in turn, inculcate in their children the advantages of their own enlightenment and thereby ensure the intellectual advancement of each succeeding generation. (Greenhow, Lecture, p. 10).

These were his general arguments, but on the basis of the region's unique industrial features, he was even more forthright, and it was largely on that foundation that the College of Physical Science was, eventually, to be built.

As the demand for coal grew in direct proportion to the pace of industrialisation, so deeper pit shafts were required to make new coal seams more accessible. Unfortunately, escaping gas or the collapse of the coal face caused fatal accidents, with their attendant train of social misery and deprivation. Greenhow used this example as the basis for his argument in favour of a more skilled and responsible workforce, especially at managerial level. It was vital, he averred, that young men destined for a career in mining should be trained scientifically as well as practically, in order to make the industry safer and more efficient. Specifically, he recommended that his proposed college should give the future managers 'a perfect knowledge of the sciences of chemistry, geology, mineralogy, mechanics and mathematics'. Thus, he claimed, on moral, social and economic grounds, within the mining industry alone, his case was sound and justifiable.

Having outlined that scheme, he then proposed the establishment of a school of medicine. Again, he emphasised Newcastle's advantages, through its hospital and various medical charities, which could be used in the practical training of medical students. (Greenhow, Lecture, pp. 12-13). Equally, he argued, lectures on English, law, ethics and jurisprudence would be advantageous, not only for the general public, but for the increasing number of youths entering the legal profession. By establishing 'an institution which (would) exert the most beneficial influence over the moral and intellectual happiness of the entire mass of the population in the North of England', Greenhow planned a College of Mining, Medicine, Law and General Arts, based in Newcastle. How far did these recommendations eventually became the blueprint for the College whose foundation stone was laid by Armstrong and which, for so many years, bore his name? Meanwhile, how far did Greenhow's contemporaries accept his proposals?

The Literary and Philosophical Society encouraged the debate for the establishment of a College or University in Newcastle, and invited Greenhow to elaborate on his plans at a series of meetings of the Society, beginning on the 7th June, 1831. Here, Greenhow argued that his proposals were aimed at the aspiring middle classes who, under the new political system would soon be recruited into the Parliamentary ranks. (Greenhow, Lecture, 5th April, 1831, p. 13). Estimated funds of between £40,000 and £50,000 would be required, both for the construction of a commodious building and for teaching purposes, including the remuneration of staff. The required capital would be obtained through a joint stock company whose shares would be modestly priced in order to encourage people of limited means to subscribe to the project. Each shareholder would become a governor of the college, with the right to vote both on general policy and on the appointment of staff. No pecuniary gain would accrue to the shareholders, their contribution being 'a free will offering at the shrine of science'. (Greenhow, Lecture, "Additional Considerations", 7th June, 1831, p. 5). Indeed, a prime aim of what Greenhow called 'the University of Newcastle' was to give the middle classes the opportunity of higher education in literature and science on the most moderate terms.

The curriculum was to be divided into two parts - preparatory studies and a professional course. The junior classes, following the mode of instruction at both the High School and the Academy at Edinburgh, were to learn the elements of classical and modern languages, English literature and composition and mathematics. (See Appendix I). The senior classes were to continue these subjects at a more advanced level, but with the addition of logic and mental philosophy. Greenhow's proposals were accepted in full, and, after being circulated both to members of the Society and the general public, a committee was formed to consider the matter further.

Unfortunately for Greenhow, he was the wrong man in the wrong place at the wrong time. More powerful battalions than he could possibly muster - perhaps alerted by his visionary proposals - were already being mobilised for action, a few miles to the south. On the 31st August, 1831, within weeks of the Literary and Philosophical Society's decision to proceed with Greenhow's proposal, the Dean of Durham wrote to his three prebendaries, ostensibly alerting them to the adverse effects of the Reform Bill on the Church in Durham. (Fowler, p. 23). Perhaps this was his sole concern, but in view of the timing and the dissenting and radical affiliations of Greenhow and some of his supporters, how far did the Newcastle proposals expedite developments at Durham? Certainly, Bishop Van Mildert feared 'any mongrel affair at Newcastle', (Whiting, p. 33), and the Anglican scheme proceeded with commendable - almost alarming - alacrity. The Royal assent was given on the 4th July, 1832, and the first students were admitted in Michaelmas term 1833, enabling Durham University to become established while Newcastle wrangled in committee. Nevertheless, Greenhow continued to argue that the Durham developments did not 'supersede the desirableness of an Insitution like that proposed for Newcastle, since many of the objects contemplated by it do not appear to have entered into the scheme of the Durham College, particularly the medical part of it'. (Literary and Philosophical Society Annual Report, February, 1832). The argument was valid, since Durham was based largely on Theology, whereas Newcastle contemplated Physical Science and Medicine. Unfortunately, the special committee did not have the courage of its own convictions and took a year to produce its report which it presented to the Society on the 5th June, 1832.

With hindsight, Spence Watson argued that the proposed scheme would have embraced the work being performed in his own day by the Royal Grammar School, the College of Medicine, and the Durham College of Science, (Spence Watson p. 267). This further supported the Committee's views that Newcastle's proposals complemented rather than opposed any developments at Durham. Indeed, they were not only a necessary adjunct, but an absolute requisite, both for the higher education of the youth of the district and for regional and national industrial progress.

The Press shared this view. The Newcastle Chronicle argued that the developments at Durham 'are not what we think will answer the demands and wishes of the neighbourhood and wants of the country', while the 'exclusive restrictions imposed upon the students must prevent a very large mass of the wealthy and intelligent classes of the district from taking advantage of the instruction it offers' and the Anglican propensities of its founders suggested that it would be 'too much for Theology; too clerical in spirit and too much like the old Universities to answer either public expectations or to supply the wants and demands of the middle classes of the community'.

In line with the founders of University College, London, the Newcastle Chronicle criticised the established institutions which supported the classical curriculum, to the detriment of scientific, technical and vocational education. It argued against the situation which gave 'no instruction in those branches of knowledge which are requisite to constitute eminence in mechanics, engineering, chemistry and those useful arts which are necessary for the well being of all classes.' In line with Greenhow's argument, it averred: 'It is from the middle classes and from those who feel the want of it that such an institution must spring'; and asked: 'why should Newcastle not take the initiative in such an honourable proceeding?' Furthermore, it argued that: 'Nowhere is such an institution more needed; nowhere is there a situation better suited to attain these objects than this area, where those branches of knowledge are so necessary and where they can have so extensive an application'.

Unfortunately, almost half a century passed before these ideals were realised, by which time, as Spence Watson observed: 'The chance of being first in the field had long since been lost, and the chance of even being best seems even now remote'. (Spence Watson, p. 267).

Nevertheless, Greenhow and the Committee continued with their exertions, and, under the Presidency of the Mayor, John Brandling, held a meeting in Newcastle's Guildhall on the 24th January, 1833. Although it was agreed, unanimously, to establish a College, and a Committee was appointed, it apparently lacked the necessary vision and motivation to see the scheme through to a satisfactory conclusion. First it proposed that a start should be made in rented accommodation and with a capital of only £5,000. Without genuine commitment, even these modest plans were doomed to failure. Years of work, painstaking thought and the vision of Turner, Bigge and Greenhow came to nought. Undeterred, the latter made yet another attempt by reading a further paper at the Society's meeting in December, 1834. Then, almost in desperation, in March, 1838, he proposed that, pending the establishment of the College, the Society itself should introduce lectures in Mathematics and Mechanical Science; in Chemistry, in Geology and Mineralogy, with a view to instructing those destined for careers in civil and mining engineering. Alas for Greenhow, the time was, indeed, 'out of joint'. Again, after an unforgivable delay, the Annual Meeting of the Literary and Philosophical Society, of February 1840, reported that nothing had been done in the matter, because such subjects were being taught in Durham University. Thus, notwithstanding the introduction of the engineering course there, the Committee had certainly moved ground since its apparent support of 1832. Yet Durham did not provide a complete alternative to Newcastle, whose projected University was based on the model of University College, London, being non-resident and free from religious tests. Furthermore, Durham did not have a medical school, and even its engineering course, given as it was in an Anglican establishment was not acceptable, as Greenhow had foretold, to 'many conscientious Dissenters from the Established Church, in consequence of their inability to comply with the prescribed oaths'. (Greenhow, Lecture, 5th April, 1831, p. 5). Indeed, in Spence Watson's view: 'Poor, easily satisfied Committee! For all practical purposes, so far as the Newcastle students were concerned, such college instructions might as well have been given on the moon'. (Spence Watson, p. 270). Nonetheless, undeterred, Greenhow continued his unsuccessful campaign until 1849, even to the point of memorialising the Government and the Queen herself. Thereafter, with the death of his wife, in 1850, and his subsequent removal from the district, he gave up the unequal struggle. (Welford, Vol. II p. 336).

Nevertheless, his idea was sound. As Bigge foresaw as early as 1802, Newcastle did possess the nucleus of a university through its learned institutions, while local specialist knowledge was readily available for those destined for management in the mining, engineering and chemical industries. (R.M. Glover, Remarks on the History of the Literary and Philosophical Society, 1843, p. 19). Throughout the protracted debate, the Literary and Philosophical Society gave its full support; the people themselves had listened, formed themselves into committees, and passed resolutions; the Corporation received deputations on the subject, were courteous and sympathetic, but, unfortunately, no one provided the necessary funds to bring the scheme to fruition.

Spence Watson suggested that the cause of Greenhow's failure was that he had looked too much for help from the Corporation and the Government and did not make even a modest start. (Spence Watson, p. 271). If that were so, then, at a later date, William George Armstrong was the more practical, for he not only saw the need to make educational provision, but helped to supply the means for its realisation.

But is Spence Watson's argument too simplistic? Certainly, the Corporation did little to promote the scheme. After suggesting that some of the funds of the Virgin Mary Hospital might, eventually, be available, they did nothing further in the matter. (Welford, Vol. II, p. 335). But what of the Government? Greenhow set great store by the fact that both the Lord Chancellor, Eldon, and the Prime Minister, Grey, were Northumbrians, who, knowing the local conditions, would, presumably, support the scheme. (Greenhow, Lecture, 7th June, 1831, p. 13). Unfortunately for Greenhow, a Scot by descent and education, he did not fully appreciate the depth of reactionary feeling among the English Establishment. For them, the very word 'science' was too often seen to be synonymous with 'sedition', and neither Eldon nor Grey were prepared to lend their support to such a cause. Perhaps of Eldon, of modest origin, it could be said that: 'The new middle class, having achieved its own social rise, blocked the way for the newcomers from below'. (Hans, p. 211). Equally, Greenhow misjudged the extent of Grey's reforming zeal. A right wing Whig, Grey once described himself as an 'aristocrat, both by position and nature, with a predilection for old institutions'. (Quoted in E.L. Woodward, The Age of Reform, 1815-1870, 1938, Second Edition 1961, p. 79). Thus, when faced with the choice of supporting an ecclesiastically based University at Durham, or a scientifically orientated one at Newcastle, he inevitably chose Durham.

Nevertheless, it could be argued that even without the support of Government or Corporation, Newcastle's middle classes, for whom Greenhow's college was intended, could have done more to help themselves. What, for example, were the Armstrongs doing?

Armstong, senior, who had come to Newcastle from Cumberland as a young man of modest means and few connections, was steadily making his way to fortune and local fame. (Welford, Vol II p. 99). At the time of Greenhow's first lecture, he was not only a wealthy corn merchant, and a founder member of the town's Chamber of Commerce, but, along with his friend, Armorer Donkin, was an influential and respected member of several local committees, including the Literary and Philosophical Society. No evidence has been traced to indicate his support of Greenhow's scheme, so his presumed indifference seems remarkable, if not uncharacteristic, on two counts - educational and social. Educationally, his own proven mathematical ability made him acceptable to the local scientific community as an able and erudite lecturer, which, of itself, would suggest a natural affiliation with the proposals. Socially, like many others of his class, he evinced an overt commitment to upward mobility. As Neve has observed: 'a fertile and scientific culture was generated among marginal men as a means of social legitimisation', while Thackray suggests that: 'science acted as a stepping stone for dissenting families ------ to achieve the status of Anglican landowner', (Quoted in Inkster and Morrell, 1981, pp. 179 and 180). Although the second decription scarcely fits one who was christened in Stanwix parish church in Carlisle, nevertheless, conceding that the first is a truer picture, both reflect Armstrong senior's ambitious propensities, which could have been advanced by associating with Greenhow.

As a respected member of the scientific community, as a merchant of some standing, married into the influential Potter family, with a solicitor son, newly returned from London, where his son in law was a High Court Judge, Armstrong, senior, epitomised the local middle classes whose educational interests Greenhow's proposals were intended to promote. Yet he, like many others, was less than supportive.

In his defence, it could be argued that, from the time of the Municipal Reform Act of 1835, Armstrong, senior, had become actively involved in local politics. He was returned as Councillor for the Jesmond Ward of the town, soon gaining Aldermanic honours and even the Mayoralty itself. Although such honours and responsibilities for a man in later years, could, arguably, leave him less time for his earlier educational interests, nonetheless, his influential voice could have swayed the lethargic Town Council which, in the end, proved indifferent to Greenhow's scheme.

Why such inactivity? Although described as a 'moderate reformer' was he at heart a reluctant one - the 'cautious Cumbrian' ? For instance, when appointed to a committee, in 1824, to determine whether a canal or a railway was the better means of communication between Newcastle and Carlisle, he chose the canal. (Welford, Vol. II p. 99).

Again, although equally moderate in religion, was he sufficiently Anglican, and by definition, part of the Establishment, to doubt some of the more radical views of Greenhow and his supporters from Turner's Unitarian congregation in Hanover Square? Or, like Eldon, was he prepared to remove the educational ladder by which he had achieved his own fortunate destiny, to prevent others from following? Whatever the cause, Armstrong, senior, was among those who stood aside and not only prevented Newcastle from having the North East's first university, but, more lamentably, blocked the early creation of an institution of higher education, specifically designed for the region's own industrial and professional classes.

But what of his son? As a young man in his early twenties, with the prospect of a partnership in one of the region's most successful legal practices, Armstrong can be excused for his non-participation in Greenhow's scheme. Nonetheless, when the time was ripe, many of Greenhow's proposals for improved standards in mining and engineering became the subject of Armstrong's Presidential addresses. Equally, the College curriculum of 1833 could be seen as the blue print for the College of Physical Science in whose eventual foundation Armstrong played such a notable part.

CHAPTER IV.

FROM LAWYER TO ENGINEER. ARMSTRONG'S CAREER FROM 1832 TO 1846.

When Armstrong returned to Newcastle from London in 1833, he resumed his career with the firm of Donkin and Stable, becoming a junior partner in 1835. From his own account, this was a most propitious move, as Donkin, a wealthy attorney, being childless, practically adopted him as his heir. "Such an opening in life was, of course, most attractive" noted Armstrong, in later years. "Here, it seemed, was a career ready made for me". (F. Dolman, "Notable Men and Their Work. Lord Armstrong, C.B., and Newcastle upon Tyne". Ludgate Monthly, Vol. V, October 1893, p. 575). With his future thus assured, he married Margaret Ramshaw, to whose father's engineering works in Bishop Auckland the schoolboy, Armstrong, had been a frequent visitor.

How did the Newcastle of his early marriage differ from that of his schooldays, or, more recently, when he left for London?

In the space of three years, a political revolution had taken place in both central and local government, with the passing of the Reform Act in 1832 and the Municipal Corporations Act in 1835. With hindsight, few national events could have had wider ranging implications for any individual than did the Municipal Corporations Act for William George Armstrong; to a lesser extent for his father, and, overall, for Tyneside. Indeed, it could be argued that the Act of 1835 was the launching pad which made the name of Armstrong synonymous with Tyneside for industrial innovation, personal achievement and entrepreneurial skill.

Although reluctant to identify with Greenhow's proposed College, when faced with the opportunities presented by the Municipal Corporations Act, the response of the Armstrongs was immediate and absolute. What, then, was the nature of this legislation which finally changed Newcastle from a medieval town on the banks of a sluggish river into a regional metropolis with deep water ports, docks and shipyards for about thirteen miles upstream, capable of building and refitting the largest naval and merchant vessels, and, in the process, transformed a modest young solicitor into a world renowned armaments manufacturer with only one rival?

By the early nineteenth century, criticism of the administration of the municipal corporations of England and Wales was being expressed on all sides. Although some had remained open democracies, many, like Newcastle, had developed into close oligarchies, usually with strong Tory inclinations. (Woodward, p. 459). Following the passing of the Reform Act in 1832, the Whig administration soon showed its concern for the boroughs by setting up a commission in 1833 to enquire into the state of the municipalities of England and Wales. Described as the 'postscript to the Reform Bill', the resultant Municipal Corporations Act, affecting 178 boroughs with a population of 2 million, gave administrative powers to municipal councils elected by ratepaying households with 3 years' standing. (Woodward, p 460).

The passing of the Act of 1835 was hailed in most reformed boroughs as a move towards real self government. In consequence, the work of defining the borough boundaries, dividing them into wards and drawing up lists of qualified voters, was carried out so rapidly that the first municipal elections were held within three months of the Act becoming law.

How did this affect Newcastle in general and Armstrong in particular? Hitherto, civic affairs had been increasingly vested in the prominent merchant families of the area, like the Blacketts and the Ridleys, whose fortunes depended on coal, lead, land, glass production and banking, while the unreformed constitution of the corporation gave great power to the freemen of Newcastle. (Fraser and Emsley, p. 51).

Evidence of the oligarchical nature of the unreformed corporations is seen in a modern description of Newcastle at that time.

'Municipal office passed between the members of a limited number of families -----. Thus, in 1817, Nathaniel Clayton was Town Clerk; he had held that office since 1785 and was to be succeeded in 1822 by his son John; his brother Robert was mayor and Robert's son William was sheriff. In the following year, although Robert was out of office, Henry, another son of Robert's, was sheriff'. (W.L. Burn, "Newcastle upon Tyne in the Early Nineteenth Century", Archaeologia Aeliana, 4th Series, Vol. XXXIV, 1956, p. 3).

Nepotism was equally strong in Gateshead, where an interlocking network of associations spanned the Tyne and connected the Armstrongs to some of the most influential men in local politics at that time. Gateshead was governed for many years by an able team of men led by William Henry Brockett. Typical of the close-knit factions of the day, he was connected by marriage to the industrial Crawshay family, while his brother John was a member of an influential group of lawyers, including Armorer Donkin, who were foremost in many aspects of Tyneside life. His father in law, Thomas Wilson, was a partner in the firm of Losh, Wilson and Bell. (N. McCord, "Gateshead Politics in the Age of Reform", Northern History, Vol IV, 1969, pp. 168-169). This firm, through its Cumbrian connections, already had links with Armstrong senior, while, in later years, another partner, Sir I.L. Bell and Sir W.G. Armstrong were to join forces in various important industrial, scientific and educational issues at both regional and national level.

Nevertheless, despite their inherent nepotism, these corporations were, at times, commendably responsible. Indeed, as early as 1763, Newcastle brought private legislation through Parliament enabling it to levy a parish rate to provide street lighting and a night patrol. Again, in 1786, it extended its powers to control refuse collection, traffic congestion and street trading, as well as using powers of compulsory purchase to widen existing streets and build new ones. (Fraser and Emsley, p. 52). Even so, the early nineteenth century saw increasing resentment that political power should lie in the hands of a wealthy few, and the town's dissatisfaction was expressed through the movement for Parliamentary reform. (Fraser and Emsley, p.55).

Among the ringleaders of this agitation were several members of the local medical profession including John Fife, the surgeon and co-founder, with Thomas Greenhow, of the Newcastle Eye Infirmary; Dr T.E. Headlam, physician at Newcastle Infirmary, and Dr Larkin, a prominent Roman Catholic. Others included Eneas Mackenzie, a former schoolmaster, who was by this time a well known author and publisher, and Thomas Doubleday, a noted pamphleteer, who was secretary of the Northern Political Union. Also included was James Losh, whose brother William was a leading local Whig, and senior partner in the Walker Alkali Works of Losh, Wilson and Bell, while his brother, George, was Armstrong senior's partner. (H. Lonsdale, The Worthies of Cumberland, 1873, Vol. IV, p. 147). James Losh was a Unitarian, a barrister, a future Recorder of Newcastle, and a Vice President of the Literary and Philosophical Society. Perhaps less in the mainstream of this reforming activity - but most noteworthy in this context - was W.G. Armstrong's own partner and mentor, Armorer Donkin. Thus, although not overtly involved in reform themselves, the Armstrongs were associating, at business and personal level, with those who were.

After the passing of the Municipal Corporations Act of 1835, Newcastle was governed by a council consisting of the mayor, the sheriff, 14 aldermen and 42 councillors. At the same time, the town boundaries were extended to include the adjacent townships of Westgate, Heaton, Byker, Elswick and Jesmond. In the development of the last two, the Armstrongs were to have a more than significant rôle to play.

Emerging men like Armstrong senior, and his wife's brother, Addison Langhorn Potter, took full advantage of the opportunities thus unfolding for civic preferment, each becoming in turn Alderman and Mayor of the town. In this milieu, W.G. Armstrong was to achieve his own zenith in the unremitting world of business. Those who wavered rather than support Greenhow's proposed college, did not hesitate when the opportunity for personal aggrandizement presented itself.

Meanwhile, the Whigs' plans to democratise local government did not bear immediate fruit, chiefly because so many local bodies already exercised their specialised responsibilities, leaving the post-1835 boroughs with only a limited function to perform. (F.W. Rogers, "Gateshead and the Public Health Act of 1848", Archaeologia Aeliana, 4th Series, Vol. XLIX, p. 154). This was, eventually, to be rectified through central government's expressed concern for public health - a fact that was highlighted during the cholera epidemic of 1831-32 which began in Sunderland and soon spread throughout the country. Local health boards were created during the emergency, but these were only temporary measures which were allowed to lapse when the crisis had passed. Only with the publication of the Report of the Poor Law Commissioners in 1842 was the gravity of the situation fully realised, and the government forced to act. The extent of the problem became even more apparent when Peel appointed a Royal Commission in 1843 to 'Enquire into the State of Large Towns and Populous Districts', with particular reference to their water services. With commendable foresight the remedies proposed were not those of medicine, but of improved domestic water supplies. As the Report stated: 'The importance of an ample supply of good water, accessible at a price within the reach of the poorest classes of society, and in far greater quantities than have hitherto been furnished, is a subject worthy of the greatest attention'. (House of Commons Parliamentary Papers, 1845, Vol. XVIII. Second Report of the Commission of Enquiry into the State of Large Towns and Populous Districts, p. 45. para XVII. Supply of Water).

Out of fifty large towns inspected, only twenty six were supplied with water under the provision of any Act of Parliament. Even here, the Report noted that the supply was 'very deficient', and deplored the fact that it was available only in certain parts of these towns while the poorest and most crowded areas had no supply whatsoever. Among those most criticised was Newcastle, where the Water Company supplied only 'about 1 in 17 of the dwelling houses' and where the Company's Works were 'stated to be situated so near the town that the water is sometimes contaminated with excrementitious and other matters from the common sewers'. (Report of Large Towns, p. 48). Apparently the poor of Newcastle obtained water either 'from public fountains supplied by the Water Company and paid for by the Corporation, or from sale-pants or stand-pipes at which the water is sold at a rate of a farthing a skeel - a vessel containing five gallons'. This rate was over four times greater than that charged for a private supply to a house in the wealthier parts of the town, and was the same as that charged in other towns like Nottingham 'for 79 gallons, delivered to the house and always at command'. (Report of Large Towns, p. 49).

Such findings as a whole led the Commissioners to observe that 'a copious supply of pure water cannot be secured to the poorer classes unless it is (provided by) some independent and disinterested body'. (Report of Large Towns, p. 50). In consequence, the Report stated that it should be 'imperative on the local administrative body charged with the management of sewerage and drainage to procure a supply of water in sufficient quantities not only for the domestic wants of the inhabitants, but also for cleansing the streets, scouring the sewers and drains and the extinction of fire'. (Report of Large Towns, p. 52).

The subsequent legislation meant that despite local loyalties, nepotism and vested interests, the post-1835 boroughs were now both empowered and obliged to exercise their civic responsibilities to the full.

Although unaware of it at the time, this Report and its subsequent legislation, perhaps more than any other single factor, was to become, literally, a watershed in the life of Armstrong. While the Municipal Corporations Act set the scene for his own future and brought civic honours to his father, the inquiries which culminated in the Public Health Act of 1848 finally changed W.G. Armstrong from lawyer to engineer. Thus it is appropriate to consider the history of Newcastle's water supply, and Armstrong's rôle in its modernisation.

As early as 1342 a fountain called 'the seven heads' belonging to the fraternity of the Grey Friars was operating in Newcastle, but the history of the town's water supply could be said to date from 1680 when Cuthbert Dikes erected an engine near the Sandgate for supplying the town with river water. Thereafter, for almost a century, there was little significant expansion because water to the fountains or 'pants' in the Newcastle streets was provided by the Common Council without charge to the townsfolk. (R.W. Rennison, Water to Tyneside. A History of the Newcastle and Gateshead Water Company, 1979, p. 3). However, when the water supply again proved to be insufficient for contemporary needs, the Common Council, in 1770, built a reservoir on part of the Town Moor and piped water into the town. Apparently, this supply was of remarkable quality, for, when the Council sent samples of the water from Coxlodge to be analysed, Professor Joseph Black, Professor of Chemistry at Edinburgh, was one who testified to its purity. (M.A. Richardson, Descriptive Companion through Newcastle upon Tyne and Gateshead, 1838, p. 289, note).

In the early nineteenth century, industrial and urban expansion led to Newcastle's population increasing by above thirty per cent between the census of 1831 and that of 1841, while contemporaries projected its increase being 'equally great during the next ten years'. (Prospectus of the intended Whittle Dean Water Company, 1845, p. 23). Nonetheless, the reservoirs constructed after 1770 remained the town's only sources of regular supply. (Middlebrook, p. 202). During the summer drought of 1831, following an exceptionally mild winter, the reservoirs ran dry. In the event, water was pumped from the Tyne and distributed in carts. Unfortunately, these measures coincided with the arrival at Sunderland of the country's first cholera epidemic. Not surprisingly, the epidemic had spread to Tyneside by December 1831, and continued until March 1832, causing 306 deaths in Newcastle, including that of Eneas Mackenzie, the local historian and Radical reformer. (Middlebrook, p. 205).

Unfortunately, contemporary medical knowledge failed to recognise the connection between the spread of disease, basic sanitation and the consumption of polluted water. Even so, an extensive street cleaning programme was instigated by the Council, and, when the worst excesses of the cholera epidemic had passed, they promised to improve the existing water supply by using filtered river water. This was in line with an experiment carried out by James Simpson of the Chelsea Waterworks Company who had already used sand filters to purify the Thames water. The scheme did not materialise, but, in the same month, a Subscription Water Company announced its scheme to pump water from the Tyne at Elswick to a new reservoir at Arthur's Hill. (Middlebrook, p. 202). After considerable opposition, the new company finally obtained the Royal Assent to its Bill in May 1834, (Rennison, p. 7), and the work proceeded on the scheme, which now included the use of filters. Despite its early promise, the Water Company's new filtering system was found to be defective, and its main supply, from the river at Elswick, was polluted with sewerage from the nearby town. In any event, with the continuing industrial and urban expansion of Newcastle, including the development of the Elswick Hall estate by Richard Grainger, the water supply would have been inadequate both in quantity and quality.

Meanwhile, what of Armstrong? By the 1840s he had reached a notable milestone in his career and was already on course to becoming one of the great engineers of all time. How did this metamorphosis occur? One salient feature of Armstrong's character was his capacity for hard work, coupled with his patient application to the immediate task in hand. This is seen in his assiduous attention to his legal duties at this juncture, despite his natural inclination towards science and engineering. Nonetheless, when he did relax, his recreations took two forms - fishing and mechanics - in both of which his inventive genius was given full scope. He constantly sought means of improving his fishing tackle and devised a bait basket which kept the fish at a low temperature.

(E.R. Jones, p. 15). In the event, it was during a fishing trip in Yorkshire, in 1835, that his professional and recreational interests finally, and irrevocably, merged and set him on the career for which he is now remembered. Walking by the river bank, an overshot water wheel, supplying power to a local marble works, engaged his attention. After some further study, he realised that only about one twentieth of its potential energy was being utilised. The solution to this problem led him to a deeper consideration of using hydraulic power as a motive force. Henceforward, this became his consuming passion. Although still actively engaged in law, he made time for almost daily visits to the engineering works of Mr Henry Watson in High Bridge, Newcastle, where he attempted to give his theories a practical application. Here he superintended the construction of his own models or watched the making of the theodolites, telescopes, clocks and other scientific instruments for which the works were renowned. (Dougan, p. 27). Henry Watson, along with his assistant, John Hutchinson and their sons, who were also employed at the works, were anxious to help in Armstrong's experiments. Through their practical skills and his own inventiveness, Armstrong realised his ambition to convert a column of water into a motive power by means of an automatic hydraulic wheel acted upon by discs made to enter a curved tube. This device was first tested in the Skinner's Burn adjoining the brewery of Armstrong's uncle, Addison Potter.

In December 1838, the results of his early experiments were published in the Mechanics' Magazine. Here, Armstrong eloquently argued the case for the improved efficiency of the overshot water wheel. Noting that an average fall of the existing wheels did not exceed twenty five feet, he averred that, by using his machine, "a rivulet might frequently be made to operate from eight or ten times that elevation, (whereupon) we should derive from the stream eight or ten times the power which, under ordinary circumstances would be attainable from an overshot wheel. ----(Conversely), we should obtain a given effect from one eighth or one tenth of the quantity of water which is at present generally requisite to produce an equal effect". (Mechanics' Magazine, 29th December, 1838, p. 213). Despite its obvious potential and sound principles, the machine was not an industrial success, partly because such a low power engine would have only limited industrial use, and also because leather, which was the only material then available for water seals, was inadequate in this instance. (McKenzie, p. 19). Thus, like other engineers before him, including Watt, for whom seven years elapsed between the patent and the first commercial realisation, Armstrong was to discover that inventive genius frequently outpaced available materials.

By the following autumn, he had made an improved hydraulic motor which produced five horse power from the two hundred foot head of the Newcastle water mains. (McKenzie, p. 19). Details of this were published in the Mechanics' Magazine in April 1840 when the feat was acclaimed as 'a new and most ingenious means of applying a neglected, cheap and almost boundless source of power'.

Although these early experiments identified Armstrong as an amateur engineer of considerable potential, but had no immediate industrial application, one of his biographers observed after a rare interview with an elderly Lord Armstrong: 'This was the birth of the idea which led to the invention of hydraulic machinery - an incident which deserves to take its place with that of Newton's apple and Watt's tea - kettle'. (F. Dolman, "Lord Armstrong: A Character Sketch." The Osborne Magazine, January 1897, p. 100).

Nonetheless, still undeterred, and with that characteristic perception and sound judgement which marked his future dealings, Armstrong turned his immediate attention to the more profitable sphere of electricity, without entirely relinquishing his concern for hydraulics. Like many inventors, he was led to this study by coincidence rather than intent.

Largely as a result of George Stephenson's experiments in developing the steam engine, colliery waggons in the region were hauled either by locomotives on rails or by fixed engines. During the autumn of 1840, William Patterson, who was in charge of a fixed steam engine at Cramlington Colliery, in Northumberland, noticed that, when he put one hand on the safety valve while the other was in contact with a jet of steam escaping from a small gap in the boiler, he experienced 'a curious pricking sensation' in his finger ends. (W. Watson Armstrong, "Lord Armstrong, C.B." Cassier's Magazine, March 1896, p. 489). Unknown to him, by touching the metal valve while in contact with the steam, he was creating static electricity.

Although electricity was known to the Greeks, it was not until people in the nineteenth century found new applications for its power that its further study was encouraged. Among the early British scientists involved in its development, Faraday invented the electric motor in 1821 and the dynamo ten years later, while the first electric telegraph was patented by Wheatstone and Cooke in 1837. Thus, the foundations were already laid for Armstrong's further developments. Meanwhile, men like George and Robert Stephenson, who had seen mechanical engineering develop largely by 'rule of thumb and scowl of brow', were being replaced by scientists whose theories were tested and proved by laboratory experiments. During the continuing controversy between the rival claims of the practical mechanic, and the theoretical scientist, few individuals were able to bridge the gap. In this unique gathering, Armstrong was shortly to take his place, as among equals. To his innate scientific talents, he added his legal training which enabled him to present his case so cogently and persuasively that never of him was it said, as of the unfortunate George Stephenson: 'He had no science to apply'.

Cramlington Colliery is a case in point. Here, although several people investigated the phenomenon, without drawing any satisfactory conclusions, when Armstrong did so, he not only published his findings in a series of papers on 'the electricity of effluent steam', but, in support of his hypothesis, he produced a hydro-electric machine which consisted of an insulated boiler from which steam at high pressure was forced through specially designed nozzles. Apparently, this system was recognised as the most effective means of generating electricity at that time, and continued thereafter to be used for the production of high tension electricity.

A characteristic feature of Armstrong, throughout his long life, was his unfailing regard for his native town, exemplified by sharing with it his talents and his fortune. In this instance, not only did he follow up his success by giving two lectures on hydro-electricity at the Newcastle Literary and Philosophical Society, in 1844, but in later years, as Lord Armstrong, he presented his original hydro-electric machine to the Durham College of Science in Newcastle.

According to the Fifty First Report of the Newcastle Literary and Philosophical Society, Armstrong's lectures were delivered at subsequent monthly meetings, in 1844, and, it was 'the novelty of the subject and the efficiency of the apparatus employed, (which) constituted the great attraction of the course'. (<u>Lit & Phil Fifty First Report,</u> 1844, p.8).

The Committee thought it 'a matter of congratulation' that this discovery should not only have originated in the neighbourhood, but should have been advanced by the researches of 'our talented young townsman' who was also a member of the Society. Apparently, even at this early stage in his life, Armstrong's illustrations and mode of delivery were of such a high order that they 'could scarcely be excelled'. Indeed, such was the popularity of his lectures that, in February, 1893, when as President of the Society the then Lord Armstrong delivered the Centenary Lecture, on "The Novel Effects of Electrical Discharge", he recalled how, because of the crowds attending his earlier lectures, he was obliged to enter by a window. (<u>Experimental Lecture</u> by the Right Hon. Lord Armstrong, delivered to the Literary and Philosophical Society of Newcastle upon Tyne, at its centenary celebrations, February 1893, p. 1). That he did not have to "appear without entering like a burglar" at the Centenary Lecture was, in fact due to his own generosity in ensuring that the Society had a Lecture Theatre appropriate to its needs. But that is anticipating events.

Meanwhile, the Report suggests that, although others had studied the phenomenon of the electricity of steam, 'Mr Armstrong appears to have been the only person excepting Professor Faraday who has investigated the subject to any great extent, or who has arrived at correct conclusions respecting the cause of the electrical excitation'. (<u>Lit & Phil Fifty First Report,</u> p. 8).

Armstrong had an experimental boiler and other apparatus constructed, and his findings published in the Philosophical Magazine. Apparently, his boiler was 'the first apparatus that deserved the appellation of a Hydro-electric machine'. (<u>Lit & Phil Fifty First Report,</u> p. 9). It was at this point in Armstrong's research that Professor Faraday delivered his lecture on the subject to the Royal Institution in London. In his discourse, Faraday differed from Armstrong only in stating that elecricity is produced by the water alone being exposed to friction, and that steam, as steam, produces no electricity during its emission. By contrast, Armstrong asserted that the accompaniment of a portion of water is "essential to a high development of electricity", and that the excitation takes place "where steam is subjected to friction", but without specifying whether the effect arose from the friction of the water alone, or of the steam and the water combined. Armstrong also expressed reservations in attributing the excitation exclusively to friction, while Faraday asserted, as a matter of certainty, that friction was the sole exciting cause. Nevertheless, the large hydro -electric machine at the Polytechnic Institution in London, which was reputed to be the most powerful electrical apparatus in the world, and was constructed under Armstrong's direction, upon the principle of exposing distilled water to violent friction in its passage through a wooden orifice, was complete and in operation in Newcastle in April 1843, whereas Faraday's lecture was not delivered until June of that year. At this point in their research, Faraday apparently considered that Armstrong still adhered to his original premise, whereas, in fact he had already arrived at the correct conclusion before Faraday delivered his lecture. Nonetheless, in fairness to Faraday, in publishing his findings on "the electricity evolved by the friction of water and steam against other bodies", he did fully acknowledge Armstrong's research, and referred to all his publications on the subject. (Lit & Phil Fifty First Report, pp. 10-11).

The outcome of these two men's experiments meant that, by subjecting water to friction against a wooden surface, electricity was produced more copiously than by any other previous method.

Further proof of Armstrong's remarkable achievement, especially in one who was professionally trained for the law rather than science, lies in the recognition of his work by the leading engineers of his day. When he was made a Fellow of the Royal Society, in 1846, Faraday was among those who supported his election, on the grounds of his being 'well known as an earnest investigator of physical science especially with reference to the electricity of steam'. Thomas Sopwith, the Newcastle born engineer, who was examiner to the University of Durham engineers' course, describes the event. After joining a crowded audience to hear Faraday lecture on 'his new discoveries on electro magnetism, I returned home to find my friend, W.G. Armstrong of Newcastle'. Sopwith then recalled that:

> 'On the following morning, Faraday headed a recommendation of Mr Armstrong to the Royal Society, and I accompanied him to Mr John Taylor, Professor Owen, Sir Henry de la Beche and the Dean of Westminster, who all added their names to his recommendation paper. It was well said of Faraday, "What is the Royal Society for if not for such men as Armstrong"? ' (B.W. Richardson, Thomas Sopwith, M.A., C.E., F.R.S., With Excerpts from his Diary of Fifty Seven Years, 1891, p. 232, Entry for 6th & 7th March 1846).

Nevertheless, despite Armstrong's successful incursion into electrical science, his fascination for, and commitment to the potential of water as a motive force remained undiminished.

At about the time of his first lectures to the Literary and Philosophical Society, Armstrong's uncle, Addison Potter, both as Mayor of Newcastle and as a local brewer, expressed his deep concern at the state of the town's water supply. This criticism coincided with the visit to the town of Peel's Commissioners, headed by Dr D.B. Reid, between December 1843 and January 1844. Among those who actively supported Reid in his surveys was Thomas Sopwith, whose Diary records that: 'On

11th January, 1844, a meeting of the Health of Towns Commission was held in Newcastle over which I was appointed Chairman of the first or "A" Committee. In this capacity I drew up the Report appertaining to the construction of dwellings and assisted in some other departments'. (Diary, p. 207). More notably in this context, he belonged to a group which later formed the nucleus of the Whittle Dean Water Company, in which Armstrong himself was destined to play such a significant rôle. In February 1845, Sopwith again met Reid and gave him details of these proposed new water works for Newcastle, which the latter duly noted in his report. (Rennison, p.30). Apart from criticising the cleaning and drainage services of the town which were 'in an extremely neglected condition', Reid made particular reference to the inadequacy of the local water supply, but reported that proposals were already in train for its improvement. (Appendix to Second Report of the Commissioners of Inquiry, Part II. Newcastle upon Tyne, Report on its Sanitary Conditions, by Dr D.B. Reid, pp. 161-162).

Meanwhile, the town's Subscription Water Company tried to stave off further criticism with active measures to repair their installations at Elswick and other parts of the town, as well as replacing the wooden pipes with those of iron. They agreed that, in addition to these minor works, a major review of the town's water supply was both necessary and urgent - a measure requiring Parliamentary legislation. To this end, in May 1844, a survey was made for a line of 24 inch diameter pipes to be laid west of Newcastle, from Newburn to Elswick. When the first proposals were complete, in October of that year, Robert Stephenson was invited by the directors to assess them. Although he considered them to be generally feasible, he averred that the estimated cost should have been about £4,000 higher. (Rennison, p. 19). Undeterred, the directors resolved precipitate action, knowing that a rival company was about to be inaugurated at Whittle Dean, on the line of Hadrian's Wall, and some five miles north west of Newburn. Thereupon, they agreed that a deputation should meet Hugh Taylor Land Agent to Hugh, third Duke of Northumberland, to request the Duke's permission to extract water from the Tyne at Newburn.

The Whittle Dean Water Company could not have come into being at a more propitious time. Like so many of Armstrong's enterprises, both time and tide were right. Not only did the deliberations on its formation take place while government inspectors were inquiring into the hygienic conditions of Newcastle, but, at the crucial time of its promotion, the inventiveness of Sopwith and Armstrong was ably supported by the business acumen of people like Armorer Donkin and Addison Potter.

Appropriately for Armstrong, it was during Dr Reid's visit to Newcastle in connection with the Health of Towns Commission that the early proposals to establish the new water works at Whittle Dean were being mooted on two main counts. The water extracted from the Tyne by the Subscription Water Company was of an unacceptable quality while the development of industry, with the consequent growth of the population on Tyneside, created an urgent demand for an increased supply of water to serve these needs.

Although these events somewhat antedated Armstrong's historical emergence as an industrialist in 1847, it is possible that he could have been involved, as a consultant engineer, in the development of the Whittle Dean Water Works, right from its inception. Apparently, during Dr Reid's visit to Newcastle between 1843 and 1844, not only did the Subscription Water Company acquaint him of their proposed improvements, but, more notably in this context, Sopwith became

Chairman of one of Reid's local committees, and allowed his office in the Royal Arcade to be used for its meetings. (Diary, p. 207)

The once elegant Royal Arcade, recently demolished, also housed the offices of Messrs Donkin, Stable and Armstrong. Mindful of the latter's commitment to the study of hydraulics - a facet of his life which is seldom given the prominence it deserves - and in view of his established association with Sopwith, the following hypothesis emerges. When, in February 1845, shortly before Armstrong's election to the Royal Society, Sopwith again met with Reid, and gave him details of the proposed new water works at Whittle Dean, was Armstrong already involved in the scheme, as an acknowledged hydraulics engineer, even before his appointment as the Company's lawyer and secretary? Certainly, the involvement of both Sopwith and Armstrong in the engineering aspects of the Whittle Dean Water Company is borne out in its modern definitive history :

'Sopwith had been involved in matters of sanitation and water supply, and had met Chadwick in April 1843 to discuss these subjects in relation to the Health of Towns Commission. In addition to his having been an associate of Grainger, in certain of the latter's schemes, Sopwith was a friend of William George Armstrong, their association having been recorded as early as 1839 when the two men discussed the practical applications of water power and had continued their relationship during Armstrong's early experiments on static electricity'. (Rennison, p. 35)

The modern morality, by highlighting Armstrong's later involvement with armaments, and by dubbing him 'the merchant of death', has often overlooked his more peaceful, yet equally important talents, especially his contribution to hydraulics engineering. His own contemporaries noted that, during the fifteen years of his legal career: 'He employed his leisure in following his natural bent for science'. (Watson Armstrong, p. 458). Furthermore, 'he gave his undivided heart to the pursuit of science and made a column of water lift a hundred tons'. (E.R. Jones, p. 11).

Equally, and with remarkable foresight, one of his biographers, writing when Armstrong's fame as an armaments manufacturer was at its height, noted that: 'Lord Armstrong is a great scientist, in fact the "grand old man" of science, and when the time comes for summing up his work, it will doubtless be found that the making of guns was not its most important feature, although the one which has most engaged popular notice'. (Dolman, 1897, p. 99).

Armstrong himself describes how, as early as 1838, some years prior to Dr Reid's visit, he made almost daily visits from his office to the works of Henry Watson, in nearby High Bridge, to supervise the construction of his first hydraulics machine, and in the following years had used the town's water supply in his experiments into the 'Application of Water as a Motive Power for Driving Machinery'. (Dolman, 1893, p. 573). Thus it seems feasible that he would wish to be associated with any new initiative aimed at improving the town's water supply, as much for the advancement of hydraulics as for its social implications. Equally, the involvement in the proposed water works at Whittle Dean of, among others, his friend Sopwith and the Mayor of Newcastle, his uncle Addison Potter, was secondary to his own commitment to the study of hydraulics and to the new company.

Dr Reid's Report had made detailed and protracted reference to a local study, presumably that of Sopwith, outlining the 'possibility of obtaining purer water than the river affords from a source more elevated than the town itself'. (Appendix to Second Report of the Commissioners of Inquiry, Part II, p. 162). The arguments in favour of an improved water supply were, apparently, based as much on Reid's own experience of the national scene as Sopwith's more localised recommendations in its observance that Newcastle's water supply, like that of many other towns, was inadequate to meet its growing industrial and domestic needs. Remarkably, Dr Reid's Report suggested that the river was 'the only trustworthy source of supply for the great bulk of the inhabitants' on the grounds that the region's extensive mine workings, which resulted in subsidence, gave other sources a precarious existence. (Appendix to Second Report of the Commissioners of Inquiry, Part II, p. 162). Nevertheless, he did admit that the river water near the town was affected by 'the discharge of the drains which consists of all the refuse of the dwelling houses and manufactories in the town'. Moreover, because the river was tidal at this point, the salt sea water gave it a brackish taste. Even the rain water was 'rendered very impure from the immense body of smoke disengaged from the coal fires of the private houses and manufactories of such a town as Newcastle'. These deficiencies, coupled with an inadequate filtration system gave cause for concern not only to domestic users, but also to brewers like Addison Potter, and other industrialists whose business interests depended on a constant supply of pure water. In consequence, the Report recommended the establishment of the water supply in a new location at least six miles to the west of the town and the provision of extensive reservoirs for adequate filtration. Such a site was readily available near Ryton where existing gravel beds could be adapted for this purpose. (Appendix to Second Report of the Commissioners of Inquiry, Part II, p. 164).

The Report having been published, and the desirability of a new water works at Whittle Dean having been established, the stage was now set both for its inception and for Armstrong's emergence as an engineer in his own right. The foundation of the company was first noted in Sopwith's Diary for 16th November 1844 when he recorded a discussion on the matter with Richard Grainger, the Newcastle builder who, along with Armstrong, was largely responsible for the formation of the undertaking. (Rennison, p. xviii). Moreover, although a provisional committee was appointed to develop the new water company, the initial responsibility for launching the enterprise rested largely in Sopwith, Armstrong and Grainger. Although the latter was not officially a member of the committee, he had a vested interest in the scheme through his development of the new town beyond the medieval walls, which - despite the recent imaginative transformation of its transport system and shopping facilities - still forms the basis of the present city centre. Equally, Armstrong's research into hydraulics made him an obvious choice.

Grainger's keenness is reflected in the fact that he called on Sopwith ten days later so that by 7th December 1844 they had prepared the plans for the new water works. Thereafter, the three men became actively involved in visiting the site of the proposed reservoir at Whittle Dean and in the legalities of contacting the relevant landowners, including the Duke of Northumberland.

Apart from Armstrong's engineering interest in the new company, he also became involved in his legal capacity when the firm of Donkin, Stable and Armstrong were appointed as the company's solicitors. In this connection, he wrote to J.C. Blackden, the commissioner to Hugh, the third Duke of Northumberland, outlining Grainger's plan for supplying water to Newcastle. The reply, dated 27th December, 1844, indicated that, provided 'the matter is not a mere private speculation, but one in which the inhabitants take a decided interest, we are inclined to believe His Grace will lend a favourable ear'. (Letters between Alnwick Castle and Whittle Dean Water Company, c. 1844 - 1845, from Letter Book of Hugh, Third Duke of Northumberland, Miscellaneous Letters, Vol. 32, 1844-1845, p. 181, in Alnwick Castle Archives).

A further letter, sent to the Mayor of Newcastle, Alderman Potter, on 1st January, 1845, endorsed the Duke's general support for the scheme: 'So far as the comfort of the inhabitants or the sanitary conditions of the town is concerned, His Grace conceives that such a proposal would meet with universal approbation', but adds a rider that: 'residing at some distance it is possible that objections may exist unknown to His Grace'. The Duke then sought reassurance that the Mayor and Corporation would act in the best interests of the people, whereupon he promised to add his own support to the scheme. (Letter Book, p. 186).

On the same day Blackden wrote to Hugh Taylor, the Duke's land agent for the Whittle Dean area, asking him to meet with the Company's Engineer to discuss the proposals and to report back to the Duke. Apparently, the new company intended to lay down an 18 inch diameter pipe which, because the Duke considered it 'too little', was increased, in line with his wishes, to 24 inches. (Letter Book, p. 186).

Also on 1st January, Blackden replied to Armstrong's letter, outlining the arrangements and asking him to communicate with Mr Taylor, pending the Duke's final decision. (Letter Book, p. 187). This was expeditiously given, for, on 22nd February, 1845, matters were sufficiently advanced for the Duke himself to write to his own solicitors and to Armstrong giving his assent to the scheme and for the necessary legislation to proceed through Parliament. (Letter Book, p. 237).

The Duke's personal and continued involvement in the wider issues of urban development was not unique. Indeed, several recent studies have revealed that the popular picture of the landed gentry as fox-hunting squires and Church of England parsons, concerned only with agricultural pursuits, falls far short of reality. Nowhere was the new breed of gentry, actively participating in industrial and urban progress, more apparent than in the North East. Here, since few estates escaped the development of the northern coalfield, most regional landowners were involved. (David Spring, "The English Landed Estate in the Age of Coal and Iron: 1830 - 1880". The Journal of Economic History, 1951, pp. 4-5).

Equally, it was not unusual for business and professional men like Potter, Armstrong senior and Donkin to concern themselves in matters of social improvement. With the passing of the Municipal Corporations Act, such men readily discovered 'that the affairs of a great municipalty were akin to that of business, but on a larger scale'.

The legislation and construction initiatives surrounding a town's new supplies of water, gas, sanitation and roads, presented exciting challenges which were readily accepted both for business and personal gain. Not only would improved amenities mean more profitable and efficient business enterprises, but active involvement in civic affairs could bring public and personal reward. Thus, 'to business achievement was added civic achievement', (Checkland, pp. 311 - 312), a phenomenon which was to be amply demonstrated in the composition of the first committee of the Whittle Dean Water Company.

Meanwhile, according to Sopwith's Diary, he took Grainger and Armstrong to survey the Whittle Dean area on 10th January, 1845. Sopwith had made a special study of mine surveying and engineering and was already renowned for his accurate surveys and the meticulously neat and detailed plans and sections which he produced from them. (Thomas J. Bewick, Memoir of Mr Thomas Sopwith, 1880, p. 1). Even so, the historical significance of his task was not lost on the engineer who proudly noted in his diary that he was surveying, for peaceful purposes, the same terrain formerly measured by military engineers. First came the Romans constructing Hadrian's Wall, then, almost exactly a century before the Whittle Dean project, the Military Road was laid, roughly along the same line, by General Wade's engineers during the Jacobite Rebellion of 1745. Nonetheless, Sopwith was satisfied that his survey established 'beyond all doubt that an abundant and cheap supply of water may be had at this level 360 feet above the Tyne'.

In addition to the Duke's approval, the proposals also required municipal sanction, but considering the dual interests of the leading instigators, this would not be too difficult. In the event, the letter from Blackden to the Mayor was duly laid before Newcastle Council in January, 1845, before being passed to the Town's Improvement Committee. On their behalf, Joseph Crawhall replied, the following month, to the effect that during 'an interview with Mr Armstrong, solicitor to the Committee', he was given 'a clear and satisfactory description of the whole project, and - - - a list of the Provisional Committee which contained names of the highest respectability'. (Proceedings of the Newcastle Town Council, 5th February, 1845). Armstrong's trained legal mind, and his ability to argue his case in a 'clear and satisfactory' manner must have been an invaluable asset not only to the emerging company in the delicate negotiations with landowners, with local Councils and with Parliament itself, but in his later business dealings at national and international level.

The first Committee of the new Company included not only the incumbent Mayor of Newcastle and his four predecessors, but Alderman Brockett of Gateshead. Moreover, in general terms, the Committee embodied two distinct groups - those with interests in health, including several well known medical practitioners, and some of the region's leading industrialists. In their professional capacity, all had vested interests in the development of a pure water supply in the region.

For example, the two doctors, Sir John Fife and David Blair White, were joined by Addison Potter, a brewer and a member of the house committee of the Newcastle Infirmary, which Armstrong was to endow so handsomely in later years; John Carr who was a member of the management committee of the Dispensary, and William Brockett who was interested in matters of health and water supply in Gateshead. The Committee's industrialists included a notable local engineer, Robert Hawthorn who, with his brother William, had opened an engine works by 1820, at Forth Banks, near the present Central Railway Station and opposite the works opened by Robert Stephenson, in 1824, to make locomotives for the Stockton to Darlington Railway. When Armstrong established his Works at Elswick, originally to build hydraulic machinery, these three firms marked the beginning of what, in later years, became one of Tyneside's major industries. (Middlebrook, p. 192).

Another feature of the Company's development was the number of outstanding engineers associated with it. In addition to Hawthorn, men like Simpson and Hawksley enjoyed both a national and international reputation as engineers of water works, while those like Sopwith and Nicholson were distinguished in both mining and railway engineering. (Rennison, p. xviii). From 1832 to 1845, Sopwith was occupied, not only in the Newcastle area, but in the Forest of Dean, where his detailed surveys, sections and models were included in a Report prepared for the Woods and Forests Department of the Government. Moreover, he was involved in improvements to the navigation of the River Tyne, and in numerous railway projects all over England and in Belgium. (Bewick, p. 2). In this connection, he and George Stephenson were honoured with a private audience with the King of the Belgians in April 1845. (Diary, p. 219). As well as the two Stephensons, Sopwith was closely associated with I.K. Brunel and J.M. Rendel, the engineer whose sons were destined to hold senior management positions in Armstrong's Elswick Works. Furthermore, his acquaintance with John Buddle and Nicholas Wood led to the founding of the North of England Institute of Mining Engineers and subsequently, along with Armstrong, to the establishment of the College of Physical Science. Thus the Whittle Dean Water Company, from the outset, had the benefit of talented engineers of outstanding reputation and experience, with whom, professionally and socially, Armstrong retained a mutual exchange.

During the establishment of the Company, the intermediaries appear to have performed their duties with commendable alacrity and skill, so that the first meeting was held on 6th February 1845, with the Mayor, Addison Potter, in the Chair and Armstrong acting as Secretary. The main item on the Agenda was to agree to a Bill being presented to Parliament during the forthcoming session. Its contents were approved on 10th February and four days later it was agreed that Armstrong should present the Bill in Parliament. At the same time, he again wrote to Blackden requesting the Duke's consent, while Grainger and Nicholson were made members of the Provisional Committee. A fortnight later, on 28th February 1845, a petition was read in the House of Commons requesting that the matter be referred to a Select Committee. Those who were called upon to give evidence included Sopwith, Grainger, Simpson and Armstrong who, in his legal capacity, was asked for assurances that Standing Orders had been observed, and the consent of the affected landowners had been obtained. (House of Lords Record Office, Select Committee of the House of Commons, 11th March, 1845).

After some minor objections had been settled, the Bill received the Royal Assent on 30th June 1845.

The following day, Sopwith terminated his association with the Company on his appointment as chief agent to the Wentworth Blackett Beaumont mines at Allenheads, a post which he held from 1845 to 1871. (Bewick, p. 3). Rennison suggests that, but for this alternative appointment, Sopwith would probably have remained first engineer to the Water Company and 'according to a contemporary source' would have become a partner in Armstrong's engineering company founded little more than a year later. (Rennison, p. 41).

From the outset, it was apparent that the Whittle Dean Water Company would brook no rivals. Therefore, its Provisional Committee, meeting in the Royal Arcade Offices of Messrs Donkin, Stable and Armstrong, on 21st February 1845, made a tentative offer to purchase the Subscription Water Company for £50,000, which was refused. On the same day, the Provisional Committee formed a sub-committee including Grainger, to assess the true value of its rival's holdings. Next day, an improved offer of £55,000 was made and accepted. The sale was confirmed at the Annual Meeting of the Subscription Company in June 1845, and, at a later meeting attended by Armstrong, it was agreed that the takeover would take place on 2nd August 1845. (Rennison, pp. 42-43).

With the inauguration of the Whittle Dean Water Company in 1845, the stage was set both for the opening of Armstrong's Elswick Works, within two years, and for his final metamorphosis from lawyer to engineer. The two companies were remarkable for the number of men, in addition to Armstrong, who were involved in both initiatives.

Four other men connected with the Whittle Dean project are especially noteworthy because of their direct involvement in Armstrong's subsequent career. Armorer Donkin, Armstrong's legal partner and mentor, was not a member of the Whittle Dean Committee, but was among the Newcastle Aldermen who supported the scheme, and whose legal practice was chosen to represent the Company's interests. The other three were Armstrong's uncle, Addison Potter, George Cruddas, a financier, and Richard Lambert who had studied law in London with Armstrong. This group, in 1846, formed the Newcastle Cranage Company which not only helped to develop the region's water supply, but which as Armstrong and Company helped, irreversibly, to change the whole ambience of Tyneside.

Throughout his life, Armstrong was renowned for his shrewdness in his choice of associates, and for the timing of his decisions. Never were these attributes more evident than at this vital stage in his career. His father, a successful merchant, was a member of Newcastle Town Council, his partner, Donkin, was an Alderman and his uncle, Addison Potter was Mayor. Coupled with his association with financiers like Cruddas, lawyers like Lambert and engineers like Sopwith, the stage was set for his next move.

When the Whittle Dean Water Company was opened, Cruddas and Lambert were appointed joint Managing Directors with salaries of £150 per annum, and at the first A.G.M., held on 30th January 1846, Armstrong was appointed Secretary with a similar salary. (Rennison, p. 49). At that meeting, the shareholders were told that, with the opening of the new water works, the production capacity was equal to four times the current demand. The prospectus for the Company, published a year earlier, made reference to surplus water 'for which some useful and profitable purpose (could) readily be found'. (Prospectus of the Whittle

Dean Water Company, 1845, p. 22).

Here was Armstrong's long awaited opportunity to apply his knowledge of hydraulics to commercial use, and he seized it with both hands. As early as 24th November 1845, he wrote to the Finance Committee of the Newcastle Town Council, outlining his plan for the hydraulic operation of the cranes on Newcastle Quayside, by using the existing water pressure in the pipes in the nearby streets. (See Appendix II). Armstrong was a master in the art of public relations, and presented a case with a two-fold appeal. First to the merchants and shipowners who would benefit by the speedier loading and unloading of cargo. Second, to the Corporation, who could levy more harbour dues, as less time in port enabled more ships to use the existing facilities in the same given time. Furthermore, he proposed to relieve the Corporation of any speculative outlay by offering to adapt one of the existing cranes to hydraulic operation. Should the experiment prove successful, he hoped that he would be granted a lease for at least ten years, at the present rate, for all the Corporation's cranes on the Quayside to be adapted subject to the following conditions:

1. That all the existing cranes be hydraulically operated, and that he should be given the exclusive right to erect similar cranes at locations approved by the Corporation.

2. He promised to reduce the present cost of cranage by at least 20% .

3. That, at the end of the stated term, the Corporation would take back the machinery at an agreed valuation.

In case the experiment failed, Armstrong gave an assurance that the present crane would be restored to its existing state.

Confident of success, Armstrong not only made a working model of his experiment, but in an audacious public relations exercise, he again lectured at a monthly meeting of the Literary and Philosophical Society nine days later, on 'The employment of a column of water as a motive power for propelling machinery'. In order to ensure maximum publicity of his scheme, the lecture was reported in the Newcastle Courant on 13th December, 1845.

From all accounts, this lecture was given to a very large audience, including the Mayor, Alderman Potter, and was as successful as his previous ones due, not only to Armstrong's meticulous preparation and delivery, but with the additional support of his working models and experiments. On this occasion, his aim was to promote hydraulic power, initially by using pressure from the water supply already existing in most towns. He observed that while the steam engine had become established as a motive force for both stationary and moving engines, water, as an equally important motive force, had been neglected except for turning water wheels in remote river valleys. Furthermore, he argued that whereas water possessed all the advantages of steam, except the ability to propel locomotive engines, the existing sources of water power, if properly harnessed, could determine the location of new manufacturing towns.

Armstrong then explained the characteristics of hydraulic pressure, or the science of fluids in motion and the methods by which they operate. With his customary attention to detail, this was demonstrated by pouring water into various tubes and illustrating the effect of lifting different weights. Furthermore, by extending the surface, the amount of pressure was increased, but, in direct proportion to that increase, a greater quantity of water was required. By using a model, he showed that the six existing mills on the banks of the Ouseburn - a tributary of the Tyne - could, by using hydraulic power, save the expense of the excess buildings by concentrating the whole operation in one mill. He noted that Whittle Dean would be admirable for such an enterprise, except that it was at present too remote from any local industries. Nevertheless, he observed that water might be conveyed by canal to any required location, and cited the case of Greenock, where it was brought seven miles by such means. He further noted that the rapid development of the railway system made hitherto remote and inaccessible hamlets available for such enterprising schemes.

Thereupon Armstrong produced a model of one of the cranes on the Quayside and ably demonstrated his theory by showing the ease with which the existing cranage could be adapted to hydraulic power. Human force, he noted, was very costly, yet without an appropriate alternative, man had to assume the role of a beast of burden. Under his scheme, the cost of water power would be only a third of that of manual labour. He illustrated this by placing on his model crane a weight equivalent to 1 ton 12 hundredweights. Normally, this required two men turning it at the rate of 20 revolutions a minute, but now it was raised hydraulically. The model had a regulator which, according to the setting of a pointer, could raise the weight quickly or slowly, as required.

Nor was the process limited in its application. With suitable adaptation, it was equally applicable to smaller machines, like printing presses, revolving saws, forge hammers and so on, where power, although required intermittently, was always readily available. (Newcastle Courant, 13th December, 1845). So convinced was Armstrong of the efficacy of hydraulic power that it was said of him that 'William has water on the brain'. (A. Cochrane, "Lord Armstrong", Northern Counties' Magazine, Vol. I. 1900 - 1901, p. 326).

The Town Clerk read Armstrong's proposals at a meeting of the Newcastle Town Council on 14th January 1846, (See Appendix II), along with a recommendation for their acceptance, from the Finance

Committee whose Chairman 'considered it an ingenious discovery and one that deserved the approbation of the Council'. It was further proposed that Armstrong should be allowed to commence his work as quickly as possible so that 'the Corporation would benefit even in the experiment'. After hearing several further testimonies to the 'ingenuity of the application and the adequacy of the working model', the Mayor supported the motion on the grounds that 'the Corporation could suffer no loss, and the port would immediately receive the benefit of diminished expense in the unloading of ships'. (Proceedings of the Newcastle Town Council, 14th January, 1846).

Armstrong was joined in his venture by George Cruddas, Richard Lambert, Addison Potter and Armorer Donkin, of whom the first three were directors of the Whittle Dean Water Company. The success of their enterprise is reflected in the tone of a subsequent letter, some months later, addressed by Armstrong to the Town Clerk, who described him as 'the inventor of the hydraulic crane recently erected at the west end of Newcastle Quay'.

The letter indicated that, having fulfilled the first part of his contract by testing extensively the first of his hydraulically operated cranes, he was now prepared to erect another four, of similar design near different wharves, to facilitate the loading of heavy raw materials like granite and bulk timber. "These four cranes," Armstrong maintained, "will be sufficient to proceed with at present, but others can be added afterwards as occasion shall require". He then outlined his plan with the uncompromising assertion that he hoped it would "have the effect of relieving this port from the character it justly bears of being one of the most backward in the kingdom in all that relates to the landing of goods and accommodation for ships and merchandise". On the surface, for anyone to have levelled such criticism at so august a body as the Council of the Town and County of Newcastle upon Tyne was the height of audacity, but for a thirty six year old junior partner in one of the town's legal firms to do so, was surely folly in the extreme. Or was it a measure of the regard in which the engineering propensities of 'our talented young townsman' were already held on Tyneside? Apparently confident of success, and with his characteristic attention to detail, Armstrong outlined his case.

First, he noted that the present situation under which valuable merchandise was loaded and unloaded at the open Quay amid the crush of carts around the cranes, and at the mercy of inclement weather, could be alleviated by the building of warehouses. Whereas other ports had the advantage of docks for the rapid transfer of goods, he argued that the same end could be achieved in Newcastle "without the expense of excavating basins for ships to float in, merely by clearing away the mass of ruinous buildings which lie between the New Quay and Sandgate, and erecting in their place depots and warehouses, under the charge of the custom-house similar to those which, in other ports, have been found to give so much facility and dispatch to the transaction of business". (Proceedings of the Newcastle Town Council, 9th November, 1846).

In his detailed knowledge of the facilities of the Quayside, Armstrong showed himself to be a true son of the Tyne. From the schoolboy son of a corn merchant, visiting his father's office on the Quayside, to the young lawyer in the nearby Royal Arcade, association with that bustling environment must have been a daily occurrence.

But merely improving the status quo was not one of Armstrong's most notable attributes. Like Sopwith's other associate, Isambard Kingdom Brunel, Armstrong was as much a visionary as an engineer. It could surely have been said of him: 'Men see things as they are and ask "why"? I see things as they might be and ask "why not?" '. For the first, but not for the only time in his career, he demonstrated this vision in his imaginative plans for reconstructing Newcastle Quay. He envisaged that heavy cargoes should be transported from the ships to the depots by tramways which, like the cranes, should be hydraulically operated. Similarly, hydraulic machinery would be engaged in working the hoists which would transfer the goods from the ground to the upper floors of the warehouses. The water for this motive power would be supplied from the town's pipes. Furthermore, where goods were to be weighed at the custom-house, "more for the purpose of statistical returns than for revenue", valuable time would be saved and the same purpose achieved, if the trucks were so constructed as to run over the weighing machines.

Again, with the development of the Newcastle to Berwick Railway, Armstrong saw further opportunities for expansion. He recommended that a proposed branch of that railway to the New Quay should be expedited, so that his depôts and warehouses "may communicate with the several railways which radiate from Newcastle, so as to secure all the advantages of railway transmission in conjunction with the conveyance by water which the river can afford". In this proposal alone, Armstrong showed himself to be a more speculative entrepreneur than his father, who, when improved communication between Newcastle and Carlisle was being proposed, favoured a canal before a railway.

His son's comprehensive scheme also envisaged improved accommodation for the berthing of the London to Edinburgh steamers. To this end he proposed that the New Quay should be widened to 80 feet and the Sandgate to 37 feet. Armstrong "respectfully urged" the Corporation to make a speedy decision on his scheme because of plans for the development of other ports in the river "which might divert traffic from our quay unless facilities be given at Newcastle equal to those which other docks can afford".

So convinced was he of the justification of his scheme that he suggested that if the Corporation refused to undertake it on the grounds of its speculative nature, he was:

"in a position to say that I shall be able to carry it into execution as a private enterprise, provided the Corporation deal liberally with me in the sale of the property required for the purpose, taking into due consideration that the undertaking will not only be of great importance to the town, but that it will add to their revenue by the encouragement it will give to bringing ships to the port and that it will economise their expenditure by rendering the existing extent of the Quay available, by means of accelerated delivery, for the reception of a greater number of vessels than it could otherwise accommodate". (Proceedings of the Newcastle Town Council, 9th November, 1846).

In such an event, he proposed to charge moderate rates for the cranage from the ships; for the use of the trucks and for the haulage, and was willing to enter into negotiations with the Corporation in order "to carry into effect these great public improvements".

Here, for the first time, was a public display of Armstrong's generosity towards his native town - a generosity which was to increase with his fortune and his years. Here, also, it could be argued, Armstrong showed the essential diference between himself and the two Stephensons. Whereas they were single minded in their approach to their railways and bridges, Armstrong's plan for modernising Newcastle's Quayside was holistic in scope. Not only was he concerned merely with patenting and successfully building hydraulic cranes - an achievement in itself - but with the whole operational environment of docks, wharves and sea and land transport. In this outlook, was he already emerging as a man of the twentieth century, rather than of his own time? Whatever the answer, his Quayside scheme was the final rung of the ladder which took him from lawyer to engineer and irrevocably stopped him "swinging like an erratic pendulum between the law office and the lathe".

CHAPTER V.

ARMSTRONG OF ELSWICK, 1847 - 1863.

However bright the prospect, or however desirable Armstrong's new vocation seemed to be, was it not a fallacious act to relinquish an established legal career with impeccable prospects for a mere dream? Even the irrepressible Armstrong, himself, confessed to misgivings in later years:

"When at length I resolved, about 1847, to give up my profession and start in business as a mechanical engineer, most of my friends thought I was very foolish. And, on the face of it, it was a bold thing to do - abandoning for an entirely new enterprise the large and old-established legal business which, in course of time, would become my own". (Quoted in Dolman, 1893, p. 575).

His own enthusiasm apart, one man's support, above all others, was paramount, not only at this juncture, but throughout his career. While Armstrong's father was less than willing to see his son relinquish the family's hard-won professional status, the bachelor, Armorer Donkin, saw the young man's potential genius, sympathised, and actively supported him. In his defence, Armstrong senior had shared the upward mobility of his father, John, who, from a shoemaker in Carlisle, had become a yeoman farmer in the nearby village of Wreay. Equally, Armstrong, senior, himself, coming to Newcastle as a junior clerk in a corn merchant's office, was now the owner of the firm; had married into a well established local family; was a promising member of the Town Council; brother - in - law of the Mayor, and himself a future holder of that office. Understandably, he had little sympathy with the son who, having become a partner in one of the most prestigious legal firms in the region, and the heir apparent to his senior colleague, would now relinquish such a desirable prospect for a mere speculative venture. Nor was the monetary aspect Armstrong senior's sole concern. Imbued as he was with the mores of his time, he considered that a professional career was, socially, more acceptable than an industrial one.

Fortunately, his criticism was ineffectual, although Armstrong himself acknowledged the conflict:

"The law was not, of course, of my choosing; my vocation was chosen for me, and for a good many years I stuck to the law, while all my leisure was given to mechanics. But the circumstances were peculiar. A great friend of my family's, Mr Donkin, had a very prosperous attorney's business. He was childless. When I entered his office, I was practically adopted by him; I was to be his heir. Such an opening in life was, of course, most attractive; here, it seemed, was a career ready made for me. As it turned out, of course, it meant the waste of some ten or eleven of the best years of my life - and yet not an entire waste, perhaps, for my legal training and knowledge have been of help to me in many ways in business. And all the time, although I had no idea of abandoning the law and regularly attended to my professional duties, I was an amateur scientist, constantly experimenting and studying in my leisure time". (Quoted in Dolman, 1893, p. 575).

There seems little doubt that, throughout this difficult period, Donkin backed Armstrong to the utmost. Socially, Donkin had a wide circle of friends within Newcastle's literary and scientific community, whom he entertained at regular Saturday lunches known as 'Donkin's ordinary'. The guests included several local mining engineers, like Buddle, Wood and Lamb. (Cochrane, 1909, p. 16). It seems possible, therefore, that his young partner would also join the company, and the lively discussions and debates for which Donkin's table was famous, would, no doubt, include Armstrong's latest inventions. In this atmosphere, Donkin would be able to assess Armstrong's standing as an engineer among some of the most eminent of his time. Thus, Donkin's willingness to support his endeavours is as much a measure of the younger man's engineering capabilities as of his personal esteem.

Meanwhile, events were moving ahead too speedily for anyone to reverse them. The lease for the building of four more cranes on the Quayside being granted, Armstrong arranged for them to be worked from a special 10 inch diameter main, supplied by the Whittle Dean Water Company, having been built by his friend Henry Watson, who later became a director of that Company. Dependence on friends, no matter how loyal or accommodating, was not one of Armstrong's traits, and he had already formulated his long term plans for his own factory where his experiments could become a viable commercial proposition.

All too soon the Newcastle Cranage Company found themselves at variance with some of the shareholders of the Water Company, who, at the Annual General Meeting on 30th January, 1847, complained about the use of water by the Cranage Company and about the involvement of directors of the Water Company in the new enterprise. The objection was groundless, since the Cranage Company was actually paying more for its water than other consumers. (McKenzie p. 37). Furthermore, they were acting in accordance with the Water Company's own declaration of intent which showed that 'rather than allow (water) to run to waste ---- the Company (would) dispose of it at an exceedingly moderate charge, for any purpose not detrimental to their ordinary revenue'. (Water Company Prospectus, 1845, p.22).

At the same meeting, Armstrong tendered his resignation as Secretary to the Water Company, not because of the criticism, but because of the emergence, on 1st January 1847, of a firm which was to become as well known as Tyneside itself - that of W.G. Armstrong and Company.

Donkin, Cruddas, Potter and Lambert, all members of the board of the Whittle Dean Water Company, who had joined Armstrong in developing the Newcastle Cranage Company, now joined him in what was to prove his greatest enterprise. Although their influence weighed heavily against that of his father, another equally important voice in this matter was that of Sopwith's associate, James Meadows Rendel, described by Cochrane as 'a well known dock engineer', whose sons were to play a leading rôle in the later developments at Elswick. Rendel's enthusiasm for Armstrong's application of hydraulics to the movement of cranes was so great that he told both father and son that its future development rested on the younger man setting up his own works to manufacture the machinery. Although unwilling to offer Armstrong any financial support, since he did not wish to have any direct monetary interest in the firm, his faith in the venture was such that he promised sufficient immediate orders to keep a small factory employed. (Dougan, p. 39).

In the event, capital for the Company was raised by Donkin, Potter and Cruddas each donating £5,000 with the latter adding a further £2,500 so that Lambert, who had little ready capital at that time, could have a half share. For his part, Armstrong contributed £2,000 in cash, as well as the patents of his hydraulic wheel, worth £1,000 and his crane, worth £2,000. (McKenzie, p. 38). Thus, W.G. Armstrong and Company began with £22,500 in capital, of which £19,500 was in cash.

It seems possible that the two schemes - the Whittle Dean Water Company and Armstrong's Works, from Cranage Company to Elswick - evolved together. Certainly, it is difficult to disassociate their early history and the mutual dependence of the group of five - Donkin, Potter, Cruddas, Lambert and Armstrong - on both a financial and professional basis. Even after Elswick was established, Armstrong still found himself enmeshed in the affairs of the Water Company, despite his resignation as Secretary. When Donkin died, in 1851, he left much of his estate to Armstrong, including his share in the Elswick Company. When Potter died, in 1854, his share was bought by the three remaining partners (Dougan, p. 40), and Armstrong, despite his awesome responsibilities at Elswick, succeeded him as Chairman of the Water Company, a post which he held until 1864. (Rennison, Appendix D. p. 320). Nevertheless, his interest in the Company was lifelong, and it was due to his able direction that it became the important Newcastle and Gateshead Water Company of today.

Having established the Company, it was necessary to build a factory. From the outset, the partners chose to look to the west of Newcastle where land was cheaper, and where they found a site on an estate at Elswick. This name, thereafter, was to be synonymous, in the realm of engineering, with Armstrong and Tyneside. The site of five and a half acres, near the village of Scotswood, not only gave room for expansion but had the advantages of good communication by road, rail and river. It had been owned by the Hodgson family from 1720, whose present incumbent, having represented Newcastle in Parliament for some time, had demonstrated his concern for the estate by building Scotswood Road through it to cross the Tyne by the Suspension Bridge, built in 1831. Unlike Armstrong, senior, and many other landowners, he welcomed the arrival of the railways as evidence of the country's future prosperity. Thus, when the Newcastle to Carlisle Railway, opened in 1836, was to be extended by building a branch line from the south bank of the Tyne, at Blaydon, to nearby Newcastle, he allowed it to traverse his land. Indeed, the presence of such good communications weighed heavily in the decision to build at Elswick.

Not that the communication from Elswick by river was too commendable at that time. Indeed the reverse was all too apparent. Opposite the proposed site, there were two large islands which reduced its navigational potential, and the river although capable of taking large vessels was in serious need of dredging. Some years earlier, a ship's captain, who was one of Newcastle's Parliamentary candidates, had said that although the Tyne had the potential to become 'one of the finest rivers in the world, ignorance and avarice had converted it into a cursed horse pond'. (Middlebrook, p. 112). The Tyne Commissioners, in which Armstrong senior was to play such a notable part, did not emerge for another three years, and their work was not really effective for another decade. (Dougan, p. 41). Nonetheless, the existing communications could be developed; the site gave room for expansion and the rates were lower than in Newcastle, only two miles away. Thus, Elswick had all the advantages of a prime town site with none of its disadvantages.

Shortly after Armstrong's death, a local account described Elswick as it was when he first set up his factory. A plan, which was still in the Elswick Drawing Office in 1900 and dated 29th January 1847, showed the original site, which was purchased for between £4,000 and £5,000 from John Hodgson Hind and Richard Grainger. Contemporary accounts testify to the rural nature of the area. Not only were there horse races and athletic sports, but one of Elswick's earliest apprentices recalled how he joined in the pursuit of a hare 'where the present bridge yard now stands', while partridges and pheasants regularly appeared within the boundary wall. The original letterheads of Elswick Works show the early factory with one of the islands, known as King's Meadows, in the foreground. Apparently this, and a smaller islet, were in front of the

Works for many years, until, with typical Armstrong ingenuity, and at the appropriate time, the islet was dredged away; the Meadows were absorbed into the Works and the course of the Tyne altered accordingly. Later accounts show that 'much as the face of the soil has altered, the river has been more changed. It now flows past the Works in a broad current and has been so effectively dredged that ships drawing 25 feet can now come (to) the east end of the Ordnance Department'. (A. Cochrane, "Elswick", Northern Counties' Magazine, 1900-1901, p. 7).

Apparently, as Donkin and Potter were, by 1847, quite elderly, they took little active part in the development of Armstrong's new Company. Nor, indeed, did Lambert. The full weight of responsibility, therefore, fell to Cruddas and Armstrong, with the latter taking more than his fair share.

As an octogenarian, he described those early years:

"Yes, I have worked hard in my time. For the first 15 years after starting the Works at Elswick, you know, I had a very hard struggle to make headway. During the whole of that time I never had a week's holiday and many a night I stayed at Elswick all night, working on till 10 or 11 when I had some important matter in hand, and then laying down on a couch for a few hours. But it is not hard work that kills - hard work never did anybody much harm; it is worry and anxiety that tell on one. ------- At times, I suffered from inventor's fever, I suppose and got little sleep at night in consequence. But that would be only when I was at the crisis of important experiments". (Quoted in Dolman, 1893, p. 574).

Certainly, despite his new responsibilities, Armstrong's inventive mind continued to be as active as ever, especially in the sphere of hydraulics. At about the time of his resignation from the Whittle Dean Water Company, he was working on another experiment, with Thomas Hawksley, the engineer whose evidence before the Health of Large Towns Commission had such long term consequences for Newcastle's water supply. These two developed a self-acting valve which, thereafter, was universally adopted by water companies. This automatically closed a pipe when the velocity of water passing through it reached a certain limit, thus checking any undue loss of water which could occur beyond the valve in case of a leak. (D.N.B. sub Armstrong, p. 64).

At first, the firm's correspondence and general office work was undertaken in its premises in Hood Street in the centre of Newcastle, while some of the hydraulic machinery, made to Armstrong's specifications, was still being manufactured at Messrs Watson's works. However, work started on 1st October 1847 at the Elswick Engine Works, as it was first known, which originally consisted of offices, four workshops, two houses for foremen, and stables. The first Elswick paysheet for wages, due on 15th October, amounted to £9 17s. 10d. (A. Cochrane, 1900, p.9).

The financial aspects of the enterprise were a major concern for Armstrong and his partners during the summer of 1847. Their original capital was soon eroded, with land costs amounting to £5,500, buildings £15,000 and machines £14,000. These and other outgoings soon amounted to a capital expenditure of £36,000. Fortunately, Donkin and Cruddas came to the rescue by depositing a further £7,000 between them, and, through their personal contacts, raised a further £17,000 at 5% interest. The capital thus stood at £43,000. (Dougan, p. 43). Nevertheless, orders had to be won quickly if the cash flow problem was to be solved.

First it was necessary to engage the men to run the organisation, and it was at this time that Armstrong made some of his most important appointments, and showed the shrewdness in assessing personal values, which was to be his -and Elswick's - trade mark for the remainder of the century. Several such men came from existing engineering firms on Tyneside. For instance, Armstrong persuaded George Hutchinson to leave

Watson's High Bridge Works, where many of his original inventions had taken shape, and come to Elswick as his assistant. Indeed, Hutchinson was subsequently regarded as Armstrong's second in command. Henry Thompson, also from Watson's Works was appointed works' manager at Elswick, while John Windlow, who was to be among the instigators of the Elswick Engine Works' Literary and Mechanics' Institute, and a Mr Singleton, were in charge of the machine shop. Furthermore, James Rowell who was involved in the Mechanics' Institute's later development, was in charge of the smiths' shop. Formerly employed at Robert Stephenson's company in Newcastle, he was engaged by Armstrong as early as 1846. After working for three days a week for the Cranage Company, he came permanently in January 1847, and assisted in the erection of the original workshops at Elswick. (Elswick Works' Mechanics' Institute Papers, in Tyne and Wear Archives Service, Accession Number 1027). According to Sopwith's Diary, he, too, 'could, if he had pleased, become a partner in this wonderful work, but he had made up his mind already that the superintendence of the Allendale Mines should be his future care, and he was not the man to change his mind even for this most tempting offer'. (Diary, 17th October, 1849, p. 236). Nevertheless, Sopwith, either personally or through his contacts, ensured many useful orders for the Elswick firm, and testified to the high standard of the firm's work, even from the outset:

'The deep drainage of the mines at Allenheads was closely investigated by me, with the valuable aid of Mr (now Sir William) Armstrong, and the hydraulic cranes placed in the mines by him met with unqualified approval and high commendation by Robert Stephenson and other competent authorities. A still higher testimony to their value has been the uninterrupted efficiency of the work performed by them, and the exceedingly small cost by which they have been kept in repair, a merit which appertains to all the extensive works of machinery which have been put up by the eminent firm of which my greatly valued friend Armstrong was the sole originator, and is yet, and I trust long will be the greatly honoured head and chief conductor'. (Diary, 1865, pp 297 - 298).

However, Armstrong was anxious to engage and train his own staff, and to this end he indentured six apprentices who started work at 6 o'clock in the morning of 20th September, 1847. Despite the early hour, as one recalled, their master arrived before them. As Robert Mills approached the new factory early that autumn morning, he saw Armstrong driving a white pony and phaeton towards Elswick. (Dougan, p. 43).

During the earlier years the engineering work included not only Armstrong's hydraulic engines and cranes, but a railway bridge for India, 20 locomotives for the same railway and 3 marine engines. Although, from the outset, Elswick produced a great variety of hydraulic machines, among the first orders for the new firm, dated 15th May 1848, was one for cranes for the Liverpool docks. Armstrong himself described how the order was placed, which helped to popularise his invention:

"Amongst others, the late Sir William Cubitt (then Mr Cubitt) took a very early interest in the machine and wrote to Mr Jesse Hartley, who was then the engineer of the Liverpool Docks, urging him to go and see it, but that somewhat eccentric gentleman, who was very averse to novelties, at first flatly refused to do so. A second letter from Sir William Cubitt put the matter in such a light that Mr Hartley could not persist in his refusal without incurring the imputation of shutting his eyes to improvements; so without giving any notice of his intention he went to Newcastle alone to see the crane. It was not at work when he arrived, but the man in charge was there, and Mr Hartley entered into a bantering conversation with him. This man, who went by the name of 'Hydraulic Jack', had acquired great dexterity in the management of the machine, and being put upon his mettle by Mr Hartley's incredulous observations, he proceeded to show its action by a daring treatment of a hogshead of sugar. He began by running it up with great velocity to the head of the jib, and then letting it as rapidly descend, but by gradually reducing its speed as it neared the ground, he stopped it softly before it quite touched the pavement. He next swung it round to the opposite side of the circle, continuing to lift and lower with great rapidity, while the jib was in motion, and in short he exhibited the machine to such advantage that Mr Hartley's prejuduces were vanquished. This was enough to convince the most sceptical observer as to the utility and importance of the invention, and so the visitor said: 'I am Jesse Hartley of Liverpool, and I have seen your crane. It is the very thing I want, and

I shall recommend its adoption at the Albert Dock' ". (Quoted in R. Cochrane, Great Thinkers and Workers, 1888, pp. 40 - 41).

Thus, Armstrong's hydraulic cranes passed from the experimental stage to one of universal adoption.

As a result of Hartley's visit, the Liverpool Docks took two warehouse lifts costing £1,000 the pair, paying the Company by cheque, on 15th May 1848 and giving the new firm its first sales revenue. (Dougan, pp. 45-46). Later that year, the Albert Docks also took two five ton cranes, while, in the previous August, Armstrong had written to Hartley offering him one of the cranes originally intended for use on Newcastle Quayside, but was never required. The asking price for this crane, built at Watson's High Bridge Works, was £700, but there is no evidence to suggest that a purchase was ever made. (A. Cochrane, 1909, p. 51).

Again, as in so many of his dealings, Armstrong was prepared for further developments. In 1848, the railway boom was at its height, and lifting gear of all kinds was in great demand. With characteristic shrewdness, Armstrong seized the opportunities presented, but unfortunately, some of the dealings were with companies as new as his own, and orders were paid for in railway debenture stock, which was something of a financial shock to the Elswick firm. (A. Cochrane, 1909, p. 52). Nonetheless, his hydraulic principle proved to be a viable proposition, and his lifting gear was in increasing demand by many of the leading experts of the day including I.K. Brunel, engineer of the Great Western Railway, who 'sent us many orders', including 'a considerable order for cranes for Paddington Station'. Another friend to the firm at this juncture was James Meadows Rendel, the well known docks engineer, and a leading exponent of hydraulics, whose support for

Armstrong, in the first instance, led to the establishment of the Works at Elswick. (A. Cochrane, pp. 58-59). When Armstrong adapted his system to operate dock gates, this attracted further work including a substantial order from Rendel for the gates at the Great Grimsby Dock, which were officially opened by Queen Victoria, who was accompanied by Prince Albert and the Royal Family. (Great Grimsby Gazette and General Advertiser, 20th October, 1854). This, the largest contract to date, amounted to £13,487. (Dougan, pp. 46-47).

Although no evidence has been found to substantiate this point, is it not feasible to suppose that, as well as Armstrong's ingenuity, Sopwith's hand was behind many of these orders? His biographer unwittingly supports this view in the following observation:

> 'Whilst occupied in (various) undertakings, (Sopwith) made the acquaintance of many eminent men, professional and otherwise. Amongst others may be named the late Messrs George and Robert Stephenson, Mr John Buddle, Mr Nicholas Wood, Mr Richard Grainger, Sir William Cubitt, (with whom he carried on a friendly and scientific correspondence), Mr I.K. Brunel, Mr J.M. Rendel and Mr Bryan Donkin'. (Bewick, pp. 2 & 6 passim).

A comparison of this roll-call with Armstrong's business associates makes both interesting and speculative reading.

Apart from the larger cranes and hoists, Armstrong soon applied the hydraulic principle to machines in general. One of his machines, a diagonal two cylinder double acting engine, after being exhibited at the Polytechnic Exhibition in London, was brought back to Newcastle and used to drive the press which printed the Newcastle Chronicle. Nor, in the midst of their personal responsibilities, did Armstrong and Sopwith forget each other, for mining machinery for the lead mines at Allenheads and winding engines for the South Hetton Coal Company were among Elswick's earliest productions.

In 1848, whereas Cochrane records that they received a large order for hydraulic machinery 'for the Lead Mines at Allenheads, owned by Mr Beaumont', (A. Cochrane, 1909, p. 56), Bewick gives credit where it is due when he notes that the 'well known hydraulic machinery for pumping, winding, crushing and other purposes at the W.B. Lead Mines was designed and erected by Sir W.G. Armstrong, acting under Mr Sopwith's instructions'. (Bewick, p. 6).

Apparently, this was both an important, and successfully executed order, although it almost resulted in the demise of these two famous engineers. During an inspection of one of the mines at Allenheads, on 16th February 1848, Sopwith and Armstrong were almost crushed to death by a water wheel. The subterranean passage they were traversing was just large enough to hold the machinery, to which was attached a huge beam which was slowly raised and lowered, in the space of ten seconds, by the action of the water wheel. The only way to pass from one side to another was to crawl, in the short interval of four seconds, when there was room to do so. The two men 'did it at the impulse of the moment, one after another, and thought little of it at the time, but a great deal of it afterwards'. (Diary, pp. 234-235).

In spite of Armstrong's able management, the engineering works at Elswick, at first, made very slow progress. Orders did not come in very rapidly, and there was some understandable difficulty in making the earlier estimates. It was not until 1850 that the tide eventually turned, and, by March 1852, three hundred and fifty men were employed, and their fortnightly wages amounted to £870. From then on, the development was steady.

One of Armstrong's admirers claimed that: 'he never did more than one thing at a time and he always followed up the idea which at the moment possessed him with a concentration which left him little attention to spare for other matters.' (A. Cochrane, 1900 p. 325). Following his success with his hydraulic cranes, he was granted a patent for a water pressure engine on 11th May, 1848. However, a more important development in hydraulic engineering was made by him in 1851, which proved to be a prime factor in making the system universally adopted.

In his early incursions into hydraulics, Armstrong, by his own admission, intended to deploy the water from the mains which would otherwise have gone to waste. He used this source for his early cranes at Newcastle and Liverpool, and, presumably, he intended it to be standard practice elsewhere. However, he soon realised that his hydraulic inventions would be of limited commercial value if they were confined to an area with an adequate water pressure from a mains supply. The problem was solved, temporarily, by constructing a tower into which water was pumped by a steam engine, but the difference between this and Armstrong's original theory was that here the steam engine, rather than the pressure of water, was the primary power source. Water, in this instance, was merely the vehicle through which that power was transmitted. Soon it became obvious that the water tower must be replaced by some other construction. (A. Cochrane, 1909, p. 59).

In 1850, the Manchester, Sheffield and Lincoln Railway ordered five two ton cranes to be erected at New Holland on the Humber, but owing to the sandy nature of the soil, it was soon evident that the construction of a water tower was impossible on that particular site. Thereupon Armstrong, with his unfailing resource, developed the notion of replacing the elevated reservoir with a large cast iron cylinder fitted with a plunger, into which an engine pumped water. With this device, the working pressure was limited only by the strength of the cylinder and its pipes. Although the storage capacity of the accumulator was, of necessity, less than that of a reservoir, nevertheless, the higher pressures involved could be maintained at a more constant level. Indeed, the customary pressure of 90 to 100 pounds per square inch could now be increased to 600 pounds, which enabled narrower pipes to be used for distribution. (Sir W.G. Armstrong, "The History of the Modern Development of Water Pressure Machinery", Proceedings of the Institution of Civil Engineers, Vol. L, 1867-77, p.71).

This invention, known as an accumulator, was soon universally adopted in a variety of usages. Later refinements to the system led to the introduction of the type of recoil cylinders used on the buffer stops at railway stations. More specifically in this context, as his guns became heavier, Armstrong increasingly used hydraulic buffers on the mountings to check the recoil. Unfortunately, the valves on this system proved unsatisfactory, so it was eventually replaced by the well known Vavasseur gun mountings, which were to be such a notable feature of the later developments at Armstrong's factory. (H.P. Gurney, "Memoir of the Late Lord Armstrong", Transactions of the Institution of Mechanical Engineers, Vol. XXI, 1900 - 1901, p.182).

Through these innovations, hydraulic machinery was, thereafter, available in every situation. Its use was particularly appropriate where power was required intermittently, and for only short periods. Thus it was particularly applicable to the working, not only of cranes, lifts and hoists, but of dock gates, berthing or launching ships, or moving capstans and turntables. Indeed, its applications are so numerous in the navy, that it has been claimed that without this invention, the development of the modern warship would have been impossible. (D.N.B. sub Armstrong, p.

65). Furthermore, its adoption proved economical both in time and money, especially at shipping and railway terminals which dealt with large quantities of traffic and merchandise. Eventually, orders were placed for hydraulically operated bridges, including Elswick's most famous ones - the railway bridge across the River Ouse near Goole, the Swing Bridge across the Tyne, which still stands on the site of the Roman Bridge of Pons Aelii, and Tower Bridge in London. (A. Cochrane, 1909, p. 63). Armstrong during his Presidential year, addressed the Institution of Mechanical Engineers in Newcastle, in 1869, on the building of the first of these, (Sir W.G. Armstrong, "Description of the Hydraulic Swing Bridge for the North Eastern Railway Company, over the River Ouse near Goole", Proceedings of I. Mech. E., 1869, pp. 121 - 132), while Stuart Rendel, in his memoirs, claimed that the Tower Bridge was "perhaps the most conspicuous engineering work in which my brother Hamilton was concerned". (Quoted in F.E. Hamer, Ed. The Personal Papers of Lord Rendel, 1931, p. 282).

Thus, within a few years, Armstrong the manufacturer not only popularised hydraulic machinery, but Armstrong the scientist and inventor, through his unwearied perseverance and wonted ingenuity, made it universally available. Again, in Sopwith's words: 'My valued friend, W.G. Armstrong, who, in addition to general science has, in this district, placed abiding records of his engineering skill, and is now occupied in adding to the number of hydraulic machines which are already in operation'. (Diary, 14th July, 1856).

With the Elswick Works now firmly established, the Newcastle Cranage Company had, by 1855, ceased to exist. However, the previous year, a more important event in the history, both of England and Elswick, had occured when this country went to war in Europe for the first time since Waterloo. This proved to be yet another major turning point in Armstrong's career, and was, ultimately, to give him and Elswick their most enduring claim to fame, not so much for hydraulics as for armaments. Early in the Crimean campaign, Elswick Works were commissioned to supply, unusually for them, some submarine mines intended to blow up the Russian ships which had been sunk at the entrance to Sebastopol harbour. Armstrong's mines were innovatory, in that they were detonated electrically. Although, as Armstrong recorded in a letter to James Rendel, the detonation system worked perfectly in tests both at Elswick and Woolwich, it was not so successful at Sebastopol, probably as much through lack of training as through the reactionary attitudes of those entrusted with their use. As Armstrong observed: "Let Engineer officers make themselves sufficiently conversant with electrical science and electrical manipulation and I will answer for it they will realise without failure the advantages which electricity affords as a means of effecting simultaneous explosions of mines". (Quoted in McKenzie, p. 54).

In the event, these incendiary devices were never used for their intended purpose, but Armstrong is reputed to have invited his principal employees at Elswick to witness the explosion of some of the fuses in his garden at Jesmond. 'It was a very pleasant function', according to a contemporary account, 'and greatly enjoyed by all the guests. The mines, planted in different parts of the field, exploded in the most exhilarating manner, and after tea had been served out, the party separated, delighted with the afternoon's entertainment'. (A. Cochrane, 1900, p.13).

This is, perhaps, one of the earliest records of the genial relationship existing between master and men during Elswick's early history - an attitude which, unfortunately, was to endure great strain in later years.

Meanwhile, another incident in the Crimean War was to change the course of Elswick's history and Armstrong's life. The battle of Inkerman, on 5th November 1854, was, apparently, fought without plan or method. Although the Allied soldiers gallantly stood their ground, they did so only with great difficulty. During the battle, two 18 pounder guns, each weighing 42 hundredweight were brought up to the crest of the hill, in the centre of the British lines, by the extraordinary extertions of 150 men struggling for three hours, over a distance of one and a half miles of rough terrain and deep ravines. This particular manoeuvre had a decisive effect on the outcome and, incidentally, on Armstrong. Although the superior range of these guns turned the tide of the battle, Armstrong, like many of his contemporaries, was appalled at the lack of progress in military strategy thus revealed, especially in military engineering compared with that of the civil sector. Naturally, Armstrong's incisive mind was soon absorbed by the subject, although more as a leisure pursuit than a serious commercial venture. Nevertheless, with characteristic resolution, he began to give considerable thought to the improvement of the heavy artillery of the British Army, which, apparently, had made little, if any, advance either in materials or design, since the Peninsula campaign and Waterloo, some forty years earlier.

When news of the events at Inkerman reached England, Armstrong was visiting the London home of James Meadows Rendel, according to the latter's son, Stuart, who, with his two brothers, was to join Armstrong at Elswick. During the ensuing discussion, the two men expressed their dismay at the ineptitude of the military engineers in retaining cast iron cannon when lighter materials had already been proved extensively in industry. Equally, they deplored the fact that rifling, universally used in small arms, had not been applied to heavy artillery. Thereupon, Armstrong began to sketch his ideas on a piece of blotting paper, at which the senior Rendel implored him to take up the challenge of applying the latest techniques of civil engineering to military purposes and bring artillery into line with modern scientific research and practice. 'You are the man to do it', he said .

Armstrong's depth of feeling for the subject was such that he promptly produced a sketch of a complete field gun and carriage, using elongated lead projectiles instead of the traditional cast iron cannon balls. Rendel duly showed this sketch to Sir James Graham, First Lord of the Admiralty, who in turn passed it on to the Minister for War, the Duke of Newcastle.

A few years later, in 1863, Armstrong - by now Sir William - in his capacity as President of the British Association, at its meeting in Newcastle, recalled the story: "In the month of December 1854, my friend Mr Rendel, the well known engineer, submitted to Sir James Graham a communication he had received from me, suggesting the expediency of enlarging the ordinary rifle to the standard of a field gun and using elongated projectiles of lead instead of balls of cast iron". (Sir W.G. Armstrong, "Report on the Construction of Wrought Iron Rifled Field Guns Adapted for Elongated Projectiles", British Association, Newcastle, <u>The Industrial Resources of the Tyne, Wear and Tees</u>, 1863, Appendix, pp. 269 - 270).

In December 1854, merely a month after the battle of Inkerman, he, "in company with Mr Rendel", was granted an interview with the Duke of Newcastle, where, as Armstrong reminisced, "I was authorised by his

Grace to carry my views into effect by constructing, upon the plan I had suggested, one or more guns, not exceeding six in number, and make the necessary experiments in connection with the subject". (Report of B. A., Newcastle, 1863, p. 270).

At this point in his life, Armstrong, for the first time, emerged not as the inventor; not even as the engineer; but as the man of science, more in tune with the ideas of the twentieth century, based on empirical research, rather than with the values of the early nineteenth century, which emphasised the practical skills. It was his commitment to scientific principles - and his vision of the consequent need for scientific and technical education - that distinguished him from either of the Stephensons and many of his contemporaries and fellow northerners, including Isaac Lowthian Bell. When commissioned to produce six guns, instead of setting to work immediately, and rectifying them in the process, by the practical man's 'mechanical instinct', as George Stephenson's generation would, probably, have done, Armstrong showed his empathy with the true scientific researcher by empirically testing his ideas in the laboratory and on field trials, before producing even one.

This was not to denigrate the practical efforts of the engineers of a previous generation. Indeed, the acrimonious debate of the miners' lamp showed that, despite Humphrey Davy's superior knowledge of the behaviour of explosive mixtures, George Stephenson's intuitive 'rule of thumb' methods, and confidence in his own ability, made him a worthy rival when, ignorant of the chemical nature of combustion, he tested his safety lamp in the deepest pocket of fire damp available. (Checkland, pp. 75-80, passim). Nonetheless, that day had passed. Faster machines, new inventions and economic forces outpaced the practical methods of an earlier time, just as the mechanical innovations in the textiles industry, a generation earlier, in turn heralded the obsolescence of the hand looms and the demise of their once proud and skilled weavers.

Meanwhile, what developments, had taken place, which separated, irrevocably, Armstrong's generation from that of George Stephenson? Well before the mid nineteenth century, there was evidence that the theorist - or natural philosopher, as he was often called - was finding areas of common ground with the practical man. Although new ideas were often resisted, it was apparent that in civil engineering, especially in bridge building, or in mechanical engineering, especially in railway construction, the standardisation of parts and the scientific testing of materials was essential if progress was to be made. Already, Rennie, who had been educated at Edinburgh University, after completing his training as a millwright, had allied theory and practice in bridge building, while George Stephenson himself acknowledged the increasing need for theoretical education in his support of the Mechanics' Institutes. (Checkland, p. 89).

In an age when every nut and bolt was turned individually, the need for a uniform system soon became apparent. Although even as late as 1851, the Great Exhibition still lauded the aesthetic skills of the practical mechanic, similar to those which the schoolboy Armstrong would remember being practised by the smiths from Crowley's of Winlaton, or Hawks' of Gateshead. Nonetheless, magnificent though these skills were, the time had come for the standardisation of machine parts and the uniformity of machine tools. Both Nasmyth and Maudslay had been concerned with 'working to gauge' for some time, but it was the latter's pupil - Armstrong's rival and eventual partner - Joseph Whitworth, who, in the 1830s, gave his name both to the threads he devised for bolts and screws, and the standard gauges he produced.

(Landes p. 207).

Meanwhile, in the constant quest for improved techniques, the British Association played a notable part by supporting research into the characteristics of materials commonly used in engineering, especially into the changes in the internal construction of metals under various conditions of manufacture. William Fairbairn and others carried out their investigations between 1843 and 1846. Indeed, it has been claimed, that Robert Stephenson, during his construction of the tubular bridge over the Menai Straits, could not have succeeded without recourse to their findings. (O.J.R. Howarth, The British Association for the Advancement of Science. A Retrospect. 1831 - 1931. 1931, p. 209).

This particular type of research was long overdue. As late as the 1860s, few British ironmasters were showing initiative of a particularly high order, and many were unresponsive to the need for scientific or technical training. (Checkland, p. 154.) Despite Henry Cort's patents of 1783 - 4, iron production still depended more on hand and eye than on scientific investigation. Indeed, the reactionary attitudes of the ironmasters, as Armstrong and Rendel probably realised, was as much to blame for impeding artillery progress as was the indifference of the military engineers. Again, this was about to change and, remarkably, it was armaments which gave the incentive. Henry Bessemer (1813 - 1898) was not a metallurgist, but one of the race of amateurs to whom Britain's industrial prowess owed so much. Early in the 1850s, he had devised an artillery shell which required a long and strong gun, but until the appropriate metal - in this case steel - could be produced cheaply, his proposition remained a mere inventor's dream. (Landes, p. 255). Although he developed the process of making steel in a convertor in 1856, and Siemens perfected his open hearth technique in 1868, it took another decade before either system was generally accepted. (Checkland, p. 155).

It was in this context that Armstrong accepted the Duke of Newcastle's challenge to build the guns.

Theoretically, his ideas were not, in certain principles, innovatory. Ballistics experts had long argued the case for 'elongated projectiles' in place of cannon balls, and considered that a rifled barrel would be more accurate than the standard smooth bore. Practically, only the heavy gun barrels then available seemed able to withstand the force of an explosive charge. The problem of combining improved accuracy with reduced weight, which beset metallurgists, mechanics and military alike, was the one which Armstrong - with Ministerial support - intended to solve. 'Perseverance generally prevails' was his favourite motto. Seldom was it more evident than in the saga of the Armstrong guns.

With his wonted application to detail, the inventor ignored the proposition to make a number of guns and, indeed, seemed reluctant to produce even one, until certain outstanding problems were overcome. The development of a safe and easily worked breech loading mechanism was recognised by Armstrong as being a major drawback in contemporary artillery. Other difficulties included, first, the absorption of the increased recoil produced in the lighter barrel without damaging the gun carriage and, second, producing a self igniting shell and shrapnel. Apparently, according to Stuart Rendel, the last named 'consumed the most time and gave the most trouble'. (Dougan, p. 57).

Yet these problems rested entirely on the need to produce a lightweight, but strong, metal. Let Armstrong again take up the story:

"I deemed it expedient to confine myself, in the first instance, to the production of a single gun, but to make that one gun the test, not only of the principles I had recommended, but also of the feasibility of loading field pieces at the breach, and applying certain mechanical arrangements to counteract recoil, and facilitate the pointing of the gun.

The substitution of elongated solid projectiles for spherical bullets is an essential step to the attainment of a very extended range in artillery practice; but the lengthening of a solid projectile involves the necessity of strengthening the gun to enable it to resist the greater intensity of force which becomes necessary to give the required velocity; and this object can only be effected, consistently with lightness, by constructing the gun of steel or wrought iron instead of cast iron or bronze".

(Report of B. A., Newcastle, 1863, p. 270).

He then produced a table showing the comparative tensile strength of the relevant materials.

	Breaking strain per square inch of section.
Cast steel, about	60 tons
Shear steel	42 tons
Wrought iron	26 tons
Bronze or gun metal	16 tons
Cast iron	8 tons.

He discarded cast steel because, at that time, it was impossible for manufacturers to produce, in any quantity, the completely flawless metal required for armaments. Nor did the other metals prove suitable. After making some experimental guns from steel and wrought iron, forged and bored in the traditional manner, he tested them to bursting point with explosive charges. In consequence, he concluded that, given the uncertainty of existing materials, he "could not define the thickness necessary to resist a given charge of powder". Thus he was obliged to "dismiss this mode of construction and to adopt another, more correct in principle but more difficult in execution". (Report of B. A., Newcastle, 1863, p. 271).

His experiments showed that although steel produced more defects than iron during the welding process, it was a harder substance which seemed to have a greater potential for his purpose. Therefore, he decided to use steel as an internal lining, and overcome its inherent weakness by "encircling it with twisted cylinders of wrought iron, tightly contracted upon the steel core by the usual process of cooling after previous expansion of heat". Thus, by shrinking the outer cylinder on to the inner one, he achieved the desired thickness and strength. But that was not the end of the matter. Soon, "considerable difficulties were encountered in carrying the plan into practice" not only with the rifling of the barrel, but with the breech loading mechanism and with the projectiles. (Report of B. A., Newcastle, 1863, p. 271).

Nevertheless, confident that "a rifled gun loaded at the breech may be more rapidly fired than a rifled gun loaded at the muzzle" and more accurately than the existing smooth bore muzzle loaded cannon, he continued his experiments to produce light, long range guns. (Report of B. A., Newcastle, 1863, p. 276).

The rifling process was to cause Armstrong - quite literally - a few sleepless nights. Alfred Cochrane's account of Elswick's early history gives the credit to William Bradley, whose indenture, signed by W.G. Armstrong, was dated 31st January, 1848. Working far into the night, and watched by Armstrong, who was unable to sleep, Bradley, who became one of Elswick's leading foremen, with more that fifty years' service with the firm, finally solved the problem. (A. Cochrane, 1909, p. 75). Nonetheless, the breech loading mechanism caused further problems, some of which endangered life, including Armstrong's own, before a satisfactory solution was found. (Dougan, p. 59). Finally, the projectile had to be produced. Paradoxically, it was medieval weaponry - archery not artillery - that brought armaments into the twentieth century. Such was Armstrong's vision, that by studying the arrow in its flight during the Crimean War, (E.R.Jones, p. 23), he produced the basic design for projectiles which would last into the space age.

Thus, all the questions of modern artillery - rifling, breech loading and projectiles - had been revolutionised by a single mind, for, as one biographer noted:

'For dealing with practical engineering problems, Armstrong had something very like genius. His vision was extraordinarily quick and penetrating; the process of his mind seemed painless; and it was this special quality in his work which was later to lead one of his enemies to ascribe to him "the genius of the accomplished amateur" '.
(J.D. Scott, Vickers, a History, 1962, p. 24).

Yet it was no amateur who produced these innovations, but an accomplished scientist whose investigations had already been accorded the ultimate accolade of the Fellowship of the Royal Society; whose feats of engineering were acknowledged, in 1850, with the award of the Telford Medal by the Institution of Civil Engineers; but who, initially, was a successful lawyer. Indeed, as contemporary evidence testifies, it was with the commitment of the born scientist, as well as with the skill of the engineer, that Armstrong produced every detail of his first gun.

'He made lengthened experiments on the strength of iron and steel, on the relative merits of cast and wrought iron, on the best number of grooves in rifling, on the best pitch or twist for these grooves, on the most convenient modes of loading at the breech of the gun, on the best form and structure of shot and shells, and on the fuses best suited for igniting the shells during their flight'. (R. Cochrane, 1888, p. 42).

Armstrong himself revealed this to the British Association in Newcastle when, for example, he showed that it was only by continued experiment and observation that he even produced the desired projectile to replace the spherical shot used hitherto. "The forms of bullet I actually tried with the gun were exceedingly numerous", he confessed, but eventually, his experiments led him to conclude that the best results were obtained when "the bullet is guided endways in its course, (and this) can only be effected by causing it to rotate rapidly upon its longer axis, (a feat) which is accomplished by firing it from a rifled bore".

(Report of B.A., Newcastle, 1863, pp. 272-273, passim).

Nonetheless, it was with the objectivity of the true researcher that Armstrong acknowledged the limitations of his invention, especially in the context of heavy artillery:

"With respect to the construction of heavy ordnance by the process of twisting wrought iron bars into cylinders, and combining them in the manner described, there appears to be no great difficulty in so doing if proper apparatus be provided for the purpose. It would not, however, be advisable (except in peculiar cases) to apply the principle of loading at the breech except to guns of small dimension, because in heavy ordnance the moveable parts would become too cumbrous to be conveniently hauled". (Report of B.A., Newcastle, 1863, p. 276).

Thus, Armstrong showed that, through the mistakes at Inkerman, he could not only produce an effective gun, but that he, more than any other, understood its limitations as well as its potential. At this point he appears no longer as the provincial lawyer, but as the scientist and engineer, pre-eminent in either field.

Armstrong's characteristic speed and efficiency can best be demonstrated by the fact that by July 1855 - a mere eight months after Inkerman - he had manufactured at Elswick the first of his now famous guns, which after certain modifications, was officially accepted for service in 1859. The original gun, a three pounder, was restored, in 1980, by the modern apprentices at Elswick Works, and is now on public display in Newcastle. The unique characteristics of this revolutionary piece of artillery were its rifled barrel and its breech loading mechanism, with a moveable vent piece, and a fused projectile 'shell' - or 'bullet', as Armstrong called it - in place of the traditional muzzle loading cannon with a ball. As a song composed in its honour, by an Elswick workman of the time, proclaimed:

'The Armstrong Gun, The Armstrong Gun,
What a wonderful thing is the Armstrong Gun.
Sir William's invention astonished them all,

With a bolt for a shot, instead of a ball'.

What effect did the machinations of an erstwhile solicitor from the remote fastnesses of the Border country have on the entrenched military and political minds in London? With remarkable understatement, Cochrane suggests that: 'The inventions of Mr Armstrong forced themselves with some difficulty upon the Government and the War Office'. (A. Cochrane, 1900, p. 14). When Armstrong audaciously offered a piece of breech loading, rifled ordnance, weighing only five hundredweight and capable of being carried by only two men, to replace the heavy artillery that was hauled up the heights at Inkerman in the previous autumn, it was derided as a mere 'pop gun' by the Artillery officers. (Watson Armstrong, p. 490). Then, when the Ordnance Committee complained that 'neither shrapnel nor common shell could be fired from it', Armstrong re-bored the gun to make it a five pounder, and produced a lead coated projectile complete with percussion fuse. (A. Cochrane, 1909, p. 76). This was duly inspected by the War Office in December 1856, whereupon Armstrong was commissioned to make an even heavier eighteen pounder gun.

All the while, Armstrong had to test his guns at various times of the day or night, either across the dene at Jesmond, beside his Newcastle home, or on the moors at Allenheads among the lead mines and sheep folds of Northumberland, causing panic among the local inhabitants and starting rumours of a Russian invasion. (C.M. Palmer, Speech at Banquet in honour of Armstrong's Knighthood, The Newcastle Journal, 14th May, 1859). During these trials, Sopwith recalled how he returned to Allenheads, on 25th July 1856, and 'found the gun experiments in full activity under the immediate and most energetic direction of William George Armstrong', when 'five out of seven of the shells passed through the target at 1,000 yards'. Later in the same year, Armstrong renewed his gun experiments at Allenheads, in the presence of Robert Stephenson. Although that engineer's opinion is not recorded, Sopwith considered 'the new contrivances to be most ingenious and effective', (Diary, pp. 244 and 258 passim), while Armstrong's adventures and narrow escapes from death during these trials, were, according to Cochrane, 'most exciting'.

Nonetheless, these admirers of Armstrong could be accused of bias, therefore a more objective assessment of the gun's potential is deemed appropriate. A contemporary account describes the tests carried out at the Government's official range at Shoeburyness in the autumn of 1858, on 'the gun of which so much has been said, though so little is really known'. In an extended series of experiments against an ordinary 9 pounder field gun, it was claimed that: 'Armstrong's gun could hit a target 2 feet 6 inches in diameter at 1,000 yards, while the service gun could not be depended upon to hit a hay-stack at the same distance'. (Dr John Scoffern, "Rifled Guns and Modern Tactics", The Edinburgh Review, Vol. CIX, No. CCXXII, Art. VIII No. 2, April 1859, p. 529).

The same author praised Armstrong's complete system of artillery. Although he claimed that the carriage showed as much ingenuity as the gun, neither contrivance, apparently, was as novel as the projectile 'on which Sir William Armstrong's fame as an inventor will ultimately be based'. (Scoffern, p. 514). Equally, it was claimed that 'the time fuse is even more curious and ingenious'. Indeed, as a result of Armstrong's invention, Scoffern maintained that 'from being one of the rudest tools, the artillery gun has now been advanced to be nearly on a par mechanically with the steam engine or the power loom, and differs as essentially from the old rude tube, formerly dignified by the name of a gun as the railway train of the present day differs from the old stage coach of our forefathers'. (Scoffern, p. 532).

At this point, the same author, perhaps unwittingly, raises the contentious issue of scientific education and technical training in which Armstrong was soon to be extensively involved. Comparing Prussian artillery with that of Armstrong, the account suggests that 'if the accuracy of the aim (of the Prussian guns) is not equal to that attained by Armstrong's gun, it is not owing to any defect in theory, but because they do not command that perfection which is found in English workshops'. (Scoffern, p. 532). This observation highlights the arguments which later raged around the issue of workshop practice versus scholastic theory and which were to become as protracted, acrimonious and impeding in the context of scientific and technical education, as were those concerning the 'religious difficulty' in the context of elementary education.

Interesting though the story of Armstrong's gun is to the general historian, it is equally so to the historian of education through the questions which it poses on the state of scientific and technical education at the time, and through Armstrong's involvement therein. Hitherto, he had shown little public interest in educational matters, thereafter, his advice was sought and his experience drawn upon by Select Committees, by eminent educationalists and by professional organisations. Thus, the development of the Armstrong gun was not only another watershed in the life of the inventor, but, more specifically in the present context, it appeared at a crucial time in the development of scientific and technical education. Indeed, it could be argued that if 'the pen is mightier than the sword', then Armstrong's claim to fame rests not so much on his development of the gun as on the consequences of that development - namely his contribution to education. Unfortunately, outside circumstances dictated that another five eventful years were to elapse before such a 'contribution' could manifest itself, by which time, he was a national figure, honoured alike by Sovereign and scholars - but that is anticipating events.

Meanwhile, despite the reluctance of the Authorities to accept his ideas, the protracted trials on his gun proved too successful to admit any further doubt. (A. Cochrane, 1900, p.14). In 1858, Major General Peel, the Secretary of State for War, being informed that Britain, unlike other countries, had no rifled ordnance for field service, duly appointed a special Committee to advise him on the best rifled gun for the purpose. (House of Commons Parliamentary Papers, 1863, Vol. XI, Report from the Select Committee on Ordnance, p. iv). After studying various reports already at the War Office, the Committee decided to experiment only with those of Joseph Whitworth and William Armstrong, although, as the Report implied, there was really only one contendent.

> 'It appears that the experiments with the Whitworth gun were not of as extended a character as those with the Armstrong gun. At that time Mr. Whitworth had not any gun of his own construction, nor did he propose any system of constructing guns. He had only rifled Government blocks of brass and cast-iron. The system proposed by Mr. Armstrong was therefore the only complete one before the Committee'. (Report Sel. Com. Ordnance, p. iv).

The climax of Armstrong's endeavours came on 16th November 1858, when General Peel's Committee reported that, having undergone extensive trials, the Armstrong gun should be adopted by the War Office for field service. At this juncture, he stood pre-eminent in the field of armaments. There was no other rival. Although alternatives, such as rifled projectiles, had been proposed, Armstrong had produced what, in modern terms, would be described as 'a complete package'. He brought before the Committee a whole new concept in artillery. Not just a weapon with a greater accuracy and range than hitherto, but an entire field system consisting of a gun, with its gun carriage for easier manoeuvrability, complete with projectiles and fuses.

One of his biographers suggests that this must have been the pinnacle of Armstrong's career.

'We can hardly imagine that any inventor has ever occupied so commanding a place as did Mr. Armstrong at this moment. His previous researches had brought him wealth and fame, but his guns must have opened up to him visions of untold riches and influence. European nations were trying to outbid each other for the possession of the new artillery, and here was the one man who had the coveted secrets and the necessary knowledge'. (A. Cochrane, 1900, p. 14).

As soon as the Government agreed to adopt Armstrong's system, he was able to state his own terms. Because he held the patents, he was in a monopolistic position whereby he could either introduce and patent further developments, or he could establish very lucrative business deals with foreign countries who were eager to buy the latest technology.

Instead, he took a remarkably generous and unselfish course by making a gift of all his patents to the Government. General Peel, in a speech on Army Estimates to the House of Commons thus described the gesture:

"Great as had been the ingenuity and talent displayed by Sir William Armstrong in regard to this invention, they were exceeded by the liberality with which he at once presented to the Government his patents and drawings - the result of ten years' experiments - without condition or stipulation". (Hansard Volume CLII, Column 1319, 1859).

While the Prime Minister and General Peel were discussing a remuneration commensurate with the gift, Armstrong relieved them of further responsibility by agreeing to enter their service as Engineer for Rifled Ordnance to the War Department, with a salary of £2,000 a year. As it was now essential to produce a large number of guns in a short period of time, Armstrong, as part of the deal with the Government undertook to produce them at Elswick, with the sole stipulation that if, for any reason, the contract ceased before he had recouped his expenses, the Attorney General of the day should act as arbitrator to decide on the appropriate compensation. Equally, as Peel noted, it was the Government's intention to make similar guns at Woolwich, under Armstrong's supervision. (Hansard Volume CLII, Column 1320, 1859).

This new departure was a major turning point in the history of Elswick. To meet the Government's requirements, the Elswick Ordnance Company was formed on 25th January, 1859, under the partnership of George Cruddas, Richard Lambert and James Rendel's son, George. In order to allay accusations of benefiting from his Government position, Armstrong had no pecuniary interest in this business, but continued to direct his original hydraulic engineering works nearby. (A. Cochrane, 1900, p. 14). Nevertheless, it would seem that his was the guiding spirit as much in the Ordnance Company as in the Engine Works - especially in the choice of men destined for future management. Not only was George Rendel brought into partnership from the outset, but, shortly afterwards, Andrew Noble, a Captain in the Royal Artillery, who, with considerable experience in gunnery, had been secretary to General Peel's Committee on Rifled Cannon, was invited by Armstrong to join the Ordnance Company as Joint Manager with Rendel, and became a partner in 1861. (McKenzie, p. 69).

Originally, the Elswick Ordnance Company was formed solely for the purpose of fulfilling Government contracts under the direction of the Secretary of State for War. The terms of reference indicated that guns were to be made for no other Government but Britain, which, for its part, would ensure full and constant employment to the firm. This arrangement continued, amicably, for about three or four years, until the original enthusiasm of the Government began to wane, in 1862, and they abandoned the Elswick firm entirely the following year. This seemed to be an unpredictable move, in view of Armstrong's own evidence before the Select Committee on Ordnance, in 1863: "The country obtained its object in getting for its immediate purposes a system of rifled ordnance which was superior to any that could have been brought against it, and the efficacy of which was proved in the China War". (Report Sel. Com. Ordnance, p. 136, para. 3163). Further evidence of the importance of Elswick Ordnance Company can be gleaned from the actual orders of the War Office which amounted to £1,067,000 between 1859 and 1863. (A. Cochrane, p. 14). Equally, guns were supplied to the Admiralty, including the 110 pounders for H.M.S. 'Warrior', the Navy's first iron-clad battleship, built in 1860, and claimed to be the world's largest and fastest warship. (McKenzie, p. 72).

Meanwhile on taking up his appointment as Engineer of Rifled Ordnance to the War Department in February, 1859, Armstrong was knighted and made a Companion of the Bath - an honour described by General Peel as 'well deserved, and which, by her own special and personal desire, had been conferred upon him by Her Majesty'. (Hansard Volume CLII, Column 1320, 1859). In the following November he became Superintendent of the Royal Gun Factory at Woolwich. The factories at Elswick - both the Engine Works and the Ordnance Company - were prospering. Armstrong, at this point in his career must have been an extremely satisfied man. Nonetheless, he was not to enjoy the fruits of his success for long. Already his enemies were bent on denigration of a most vindictive order. They came from two main quarters - the Army officers whose reactionary attitudes argued for the restoration of the muzzle loading guns, and the armaments manufacturers led by Whitworth, who would brook no rival.

As early as March 1860, questions were being asked in Parliament which insinuated that Whitworth's guns were better than Armstrong's, but had not received the attention they deserved. (Hansard Volume CLVI, Column 2221, 1860). During Armstrong's tenure at Woolwich, Stuart Rendel suggests that he had 'transformed it from a mere gun foundry into being equal to the manufacture of modern rifled ordnance'. (Hamer, p. 274). Nonetheless, he had never taken to public life and was not at ease in the cut and thrust of public debate - a factor which his rivals were prone to exploit. By contrast, Whitworth, the main protagonist, brought his own ideas to the attention of the authorities with such conviction that no fewer than seven official committees reported on his designs. Even so, none had either given him the recognition he sought, nor had they eased the pressure that he and his sympathisers were able to exert on Armstrong. (Hamer, p. 274). In the end, a Special Committee was convened on 1st January, 1863, to examine the two rival systems of Armstrong and Whitworth and to report accordingly. So searching was the enquiry that the Armstrong and Whitworth Committee sat for three years and was reported to be 'unrivalled among artillery investigations in scope and thoroughness'. (Hamer, p. 275).

In addition to this official enquiry, the debate continued, unofficially and often acrimoniously, through the press, and even in books. A former Colonial official, Sir James Emerson Tennent, convincingly told The Story of the Guns, ostensibly to uphold Whitworth's claim to justice, but this was immediately refuted by Another Story of the Guns, written by Charles Bowin, under the nom de plume of 'The Fraser Reviewer', and aided in no mean part by Stuart Rendel. (Scott, p. 24, note 6). The latter, by now a practising lawyer, was Armstrong's civilian representative on the Armstrong and Whitworth Committee.

Meanwhile, Woolwich considered itself capable of meeting all the Government's requirements for ordnance, so the arrangement with the Elswick Ordnance Works was terminated. Feeling very keenly the invidiousness of his position, Armstrong resigned his appointment with the War Office and returned to Elswick in 1863. (S. Rendel, "Some Early Memories of Lord Armstrong", Armstrong Whitworth Record, Vol. I No. 3, Spring 1931, p. 8).

Despite his commitment and outstanding contribution to scientific and engineering development, especially in the fields of electricity, hydraulics and ordnance, Armstrong, until 1863, displayed no outward interest in the obvious corollary to his studies - the development of the appropriate technical education. Why? Perhaps as an amateur scientist himself, whose professional education was in another discipline, he shared Robert Stephenson's views, who, with his father's example in mind, 'believed not that the world was full of "mute inglorious Miltons", but that, come what may, talent will find its way to the top'. (Rolt, p. 326).

Certainly, Armstrong gained little from the example of Robert Owen, whose schools at New Lanark, catering for all ages in the community, were, from the outset, an integral part of his factory. 'Owen knew what kind of education he wanted, and what he meant it to effect. ----From the moment when he assumed control of the mills, he began planning the means of putting his educational ideas into practice'. (Cole and Postgate, The Common People, 1746-1946, 1971, p. 127). By contrast, Armstrong's positive commitment to education was slow to emerge. For instance, Greenhow's plea to the Literary and Philosophical Society to establish a College for scientific education in Newcastle was ignored by both Armstrong and his father. Nor did he actively participate in the development of University College, London; in Durham University; or in the Newcastle Mechanics' Institute. Throughout all these innovations he seems to have pursued his own career to the exclusion of all else. But that was soon to change.

Already, he had appointed a team of talented young men to positions of high responsibility at Elswick. These included Percy Westmacott, the son of an Edinburgh professor, who, when the Ordnance Works were started at Elswick, became manager of the established hydraulic machinery department, while George Rendel, at 26 years of age, was appointed manager of the new Ordnance Works. On Armstrong's return to Elswick, Captain (later Sir) Andrew Noble - who eventually succeeded Armstrong as principal of the firm - became manager of the ammunition department, a post described by Stuart Rendel as 'then of great importance'. (Quoted in Hamer, pp. 272 - 273). The younger brothers of George Rendel - Hamilton 'a born engineer', and Stuart, a lawyer and later Lord Rendel - also joined the firm and held senior positions.

It was in a tribute to these youthful managers that, when someone spoke of the outstanding success of the Armstrong firm, that the fourth Rendel brother replied: 'What else could you expect? No engineering firm ever contained so much brains'. (Quoted in Hamer, p. 283).

Now, on his return to Elswick, Armstrong realising that the success of his firm depended as much on his skilled workforce as on his enterprising young managers, became actively involved in promoting the Elswick Works' Mechanics' Institute, and soon built schools for the children of his employees.

Nor was his commitment to education merely parochial. His experience in giving evidence before the various Committees on Ordnance served him well when invited to state his views during the later enquiries into scientific and technical education, at national level. At the same time, the cultural needs of his native town were not forgotten. While earlier cries for scientific education went unheeded, Armstrong answered later requests both promptly and effectively.

CHAPTER VI.

ARMSTRONG AND THE ELSWICK MECHANICS' INSTITUTE 1848 - 1863.

As Armstrong's factory expanded, and greater skills were demanded, how did he and his workforce react to the challenge of change in an age where the necessary education was difficult to obtain? One important development was the emergence of the Elswick Mechanics' Institute which, allowing for modifications appropriate to contemporary needs, existed until 1971.

How typical, or atypical, of the general trend in Mechanics' Institutes was Elswick? Was it unique, or even notable? What was Armstrong's rôle in its development? Did he instigate this enterprise, or was he the catalyst for its development?

During the summer of 1847, Armstrong had made several important appointments to his Works, including John Windlow, who was foreman in the machine shop. (E.W.L.M.I. Papers, in Tyne and Wear Archives Service, Accession Number 1027). Windlow is credited with having instigated the Elswick Engine Works' Literary and Mechanics' Institute, when he invited a group of his fellow workmen to meet in his cottage in December 1848 'for the laudable object of mutual improvement'. (See Appendix V, Armstrong's speech at the opening of the new building, 1863).

The general history of the Mechanics' Institutes has been too well documented to require repetition, except to note that even as early as 1832, at the time of the Reform Bill, many of them had failed to live up to their original aims of educating mechanics in the scientific principles of their respective trades. Nevertheless, in many parts of the country, there were still groups of men who gathered together, often in their own homes, to discuss topics of mutual concern. The sporadic nature of these voluntary, mutual improvement societies makes it difficult to assess their true value but Hudson noted that: 'In all the Northern Counties (the years) 1849 and 1850 have witnessed a general movement amongst the village population to establish reading rooms and libraries, while the smaller towns have fostered and encouraged the mutual improvement societies and youths' guardians' associations'. (J.W. Hudson The History of Adult Education, 1851, 1969 reprint, p. 191).

Thus Windlow was following an already established trend when he started a mutual improvement society in his cottage in a street then known as 'The Fisheries' which was to the west of the Works' Brass Foundry. (E.W.L.M.I. Papers).

Little more is known of Windlow, or if he intended to establish a Mechanics' Institute from the outset. Nonetheless, there is some contemporary evidence of comparable educational provision in the region, against which to measure the Elswick experience.

'The inhabitants of Newcastle upon Tyne have furnished abundant evidence ---- of their appreciation of the value of mechanical, artistic and chemical skill. The Literary, Scientific and Mechanics' Institute (in Newcastle) was established in 1824 and soon occupied a prominent and influential position in the district. There are two flourishing men's reading rooms (in Newcastle), and Mechanics' Institutes in Gateshead, in North and South Shields, Wallsend and Tynemouth. The populous villages supported by the prolific collieries in the locality have their own cheap newsrooms and Mechanics' Institutes'. (Hudson, pp. 140 - 143, passim).

The absence of hard evidence makes it difficult to assess the educational value of Windlow's early classes. Nonetheless, in an area of scarce educational resources, like Elswick, they must have satisfied a real need since, in the early stages, they provided both elementary and vocational instruction for the workmen. Thereafter, they must have kept ahead of educational demand, in the face of growing competition from other quarters, otherwise they would not have continued to prosper.

Even at this early stage, there is evidence of Armstrong's personal involvement in this educational scheme, despite his business worries. As the demand for tuition increased, particularly among the young apprentices, the number of pupils could no longer be accommodated in Windlow's home. When he discussed the problem with Armstrong, personally, the latter agreed to purchase a three roomed cottage near the Works to house the classes. Thereafter, until its demolition in recent times, the adjacent road was known as 'School Street'. Notably, from the outset, one room of this cottage was assigned as a reading room and library, thus establishing the tradition of a Mechanics' Institute, although it was not designated as such at that time. (E.W.L.M.I. Papers).

In an attempt to increase the proficiency of the apprentices in his charge, Windlow taught them not only the three Rs but Geography and History. The inclusion of the latter is especially noteworthy in view of the prevailing attitudes towards such teaching in the Mechanics' Institutes. The Report of the Select Committee on Public Libraries indicates that: 'The reading of the people has tended towards a deeper style than formerly (and) the working classes prefer historical and political works'. (Report of the Select Committee on Public Libraries, 1849, paragraphs 1219 and 1222). Nevertheless, few Mechanics' Institutes allowed such books in their libraries in case such study would incite riotous behaviour, or interfere with the status quo. It is therefore indicative of Armstrong's liberal outlook as well as his trust in his workforce, that he allowed such studies to take place. By contrast, members of the Manchester Mechanics' Institute claimed that 'chemistry and mechanics were not sufficient' and recommended a broadening of the curriculum so that members 'might be educated as a citizens'. When a History class was requested, there, the directors rejected it on the grounds that 'it would lead to the introduction of political debates'. (D.S.L. Cardwell, (Ed.) From Artisan to Graduate, 1974, p. 64). By circumscribing the curriculum in this way, many patrons of the Mechanics' Institutes forced the members to form their own working men's associations.

That being the case, why did Armstrong place no embargo on such studies? It could be argued that, while the men were meeting in their off duty hours and in the home of a private individual, he had no jurisdiction over them. Nevertheless, when the numbers increased and they met, thereafter, in premises belonging to Armstrong's firm, they still continued to enjoy his full encouragement and active support.

What motivated him? Was it religion? Was it the social uplift of his fellow man? Was it economics? Whatever factor sustained his interest in the later years of the Institute, it should be noted that, from the outset, despite his own worries for the financial viability of Elswick, he gave the lower grades of his employees every opportunity to further their qualifications and to rise to positions of reponsibility within the firm.

From the outset, he must have realised that he was competing for a skilled labour force with established local firms like those of Robert Stephenson at Forth Banks and Watson's at High Bridge. Thus, he needed some unique incentive, first to attract his men and then to retain them.

One solution would be to have his own educational establishment which would be seen by the men as a ladder to promotion, either within the firm or elsewhere. The fact that so many stayed with Armstrong throughout their working lives is indicative of the success of his scheme. One reason for its success could be its democratic origins, which Armstrong endorsed.

By supporting the Mechanics' Institute, he was not only investing in the future of the firm and enabling the men to aspire to greater heights of personal and professional achievement, but as a non-trained engineer, the gains for Armstrong and his men could be reciprocal.

As he admitted some 40 years after the opening of Windlow's mutual improvement classes at Elswick, "I have passed through the stage of being treated as an amateur and a theorist, not likely to succeed for want of practical acquirements". (Lord Armstrong, "The Cry for Useless Knowledge", The Nineteenth Century, Vol. XXIV, No. 141, November 1888, p. 653).

Percy Westmacott, who began as a draughtsman at Elswick in 1848 and who rose to senior management, recalls those early years. 'There was little or nothing of the trained element at the Works then. Mr Armstrong held the unique position of serving an apprenticeship at the same time as he was Master'. (Quoted in McKenzie, p. 120).

At this stage, there are similarities between Armstrong's attitude towards his workmen and that of George Birkbeck and the mechanics of Glasgow who made the apparatus for his lectures:

'I beheld such strong indications of the existence of the unquenchable spirit that the question was forced upon me: Why are these minds left without the means of obtaining that knowledge which they so ardently desire and why are the avenues of science barred to them because they are poor?'. (Birkbeck's speech at the opening of the London Mechanics' Institute, 1823, quoted in T. Kelly, George Birkbeck, 1957, p. 28).

It could be argued that while Birkbeck was acting impartially, Armstrong was motivated by more than a little self interest. In the final analysis, any educational expenditure, either of time or money, was bound to be reflected in the firm's balance sheets. Nonetheless, unlike many industrialists in similar circumstances, Armstrong did provide such education for his employees.

Meanwhile, what kind of man was Windlow? Armstrong not only made him a foreman in his new factory, but entrusted the education of the apprentices to his capable hands. Obviously a man of foresight and leadership, was Windlow the product of a Mechanics' Institute? Or was he, like George Stephenson, so aware of his own lack of education that he tried to ensure a better future for his successors? Although no relevant records exist, it is possible that he had attended the Newcastle Mechanics' Institute, which opened in 1824. This hypothesis is based on the assumption that Windlow, like Robert Stephenson and Armstrong, was one of the new generation of engineers, standing at the interface of the new developments.

Unlike George Stephenson and the pioneers of the Industrial Revolution, this new generation needed to apply empirical as well as practical skills in order to harness the new technology. Robert Stephenson, having studied at Edinburgh University, was soon rivalling his father's fame as an engineer not only in his work on the Liverpool to Manchester railway, but as a bridge builder of note when, only a year after Windlow started his classes at Elswick, he opened the High Level Bridge at Newcastle, and, in the following year, the Royal Border Bridge at Berwick. Without these two feats, the East Coast rail link between London and Edinburgh would have been impossible.

Fortunately for the younger Stephenson's reputation, these two successes followed hard on the heels of a disastrous failure when the Dee Bridge on the Chester to Holyhead Railway collapsed as a passenger train was passing over it. (Rolt, pp. 300-301). Both he and Armstrong learned, from bitter personal experience, that the soaring visions of the inventor had outpaced comparable developments, either in machine tools or metallurgy. Thus, their theories were far in advance of immediate practical application. Frequently, when Armstrong experimented with his early guns, sometimes in the presence of Stephenson himself, he realised that his own life was in greater danger than that of any potential enemy. These failures alone must have made Armstrong realise the urgency for future engineers to be as familiar with laboratory techniques as they were with workshop practice. It is in this context that Armstrong's personal involvement with the Elswick Mechanics' Institute, and with science and education, generally, must be assessed.

Moreover, since Windlow instigated the movement which led to the development of the Elswick Mechanics' Institute, was he, equally, of this new breed of engineers - the men of theory as well as of practice; the men of the laboratory as well as the lathe? The lack of records makes such a hypothesis difficult to prove. Nonetheless, as a mature man holding a responsible position in the late 1840s, either he was the product of a Mechanics' Institute himself, or he was so much in tune with the thinking of his time that he realised that, without a thorough knowledge of the theory as well as the practice of their trades, Armstrong's workforce could not compete with their rivals. Evidence which might support such a premise appears in a different context.

Modern research suggests that the Manchester Mechanics' Institute 'was fortunate in having men qualified for their task' as teachers who 'had their heart in their work'. These men, former pupils of the Institute became such 'valuable helps' to it that Kay-Shuttleworth himself observed that 'the instruction is of a very superior character and is much more likely to attract apprentices from the shops and very skilled artisans who have received a superior education than to attract members of the operative classes alone'. (Cardwell, 1974, p. 63).

The Manchester experience is so much in line with that of Elswick as to be more than mere coincidence. Certainly Armstrong's willingness to purchase a property to enable Windlow to set up a school has to be seen in that context. At a time when Armstrong himself admitted that he paced the streets till the soles of his shoes were hot, worrying about the financial problems of his company, (A. Cochrane, 1909, p. 90), he must have been convinced both by Windlow's case and the foreman's ability to make it a success. With the benefit of hindsight, this is the earliest of countless examples of Armstrong's ability to choose the right men for a particular task and of trusting them to do it, once they were appointed. As Armstrong himself admitted, later, "I can affirm with confidence that, had I acted upon the principle of choosing men for their knowledge rather than their ability, I should have been surrounded by an incomparably less efficient staff than that which now governs Elswick". (Lord Armstrong, "The Cry for Useless Knowledge", The Nineteenth Century, Vol. XXIV, No. 141, November 1888, p. 664).

Here, Armstrong could have agreed with a modern historian's views:

'It is a great deal easier to find the capital for the construction of a modern industry than to run it; much easier to staff a central planning commission with a handful of Ph.Ds than to acquire the mass of persons with intermediate skills, technical and administrative competence and so on without whom any modern company risks grinding into inefficiency. ----At no stage did (Britain) suffer from a shortage of men competent to work metals and, as the British usage of the word engineer indicates, the higher grades of technology could readily be recruited from among the men with practical workshop experience'. (E.J. Hobsbawm, Industry and Empire, 1968, 1977 edition, pp. 61-2).

Anticipating a later debate, was Armstrong's immediate concern for the 'mass of persons with intermediate skills' the reason why he hesitated to ally himself with the proponents of the College of Physical Science?

Unfortunately, no further records remain of the early classes in School Street but, by 1859, they were sufficiently well established as to have a committee of 14 members and a Rule Book for their guidance. (See Appendix III). Moreover, they operated under the impressive title of the Elswick Engine Works' Literary and Mechanics' Institute.

The unobtrusive emergence of this Mechanics' Institute is in stark contrast to the wave of publicity which attended the founding of that in Newcastle when George Stephenson presided at the inaugural meeting in 1824. Nonetheless, while the Newcastle Mechanics' Institute became the city's public library, in 1880, the one at Elswick continued in its original form until comparatively recent times. Associated as it was with a large engineering works, it catered solely for the apprentices, mechanics, draughtsmen and engineers of Armstrong's factory. Thus, it was a Mechanics' Institute in the literal sense. Perhaps this helped Elswick to survive where others had failed.

Nor did the Institute appear to suffer from the over-bearing patronage which was such a marked characteristic of so many Mechanics' Institutes. This is understandable, given Armstrong's commitment first to the establishment of the Works, and then, by 1859, to his responsibilities as Engineer of Rifled Ordnance to the Government. Nonetheless, it will be shown in Armstrong's later speeches to the Mechanics' Institute that, despite his ability to delegate responsibility, he still exercised a benevolent paternalism over the Works and his employees.

How far did the aims and curriculum of the Elswick Mechanics' Institute reflect Armstrong's own philosophy for life, and how far were they in line with similar institutions? Moreover, who stood to benefit most - Armstrong, or his men?

The stated object of the Elswick Institute was 'the advancement of its members in the Arts, Science and in General Literature by means of Lectures, Conversaziones and Classes'. The level of study appeared to vary from the basics of Reading, Writing, Grammar and Arithmetic to the more progressive subjects like Hydraulics, Hydrostatics, Pneumatics and Phonography. The curriculum also included Elocution, which is noteworthy, since this would be useful both as a means of effective communication in daily life and for those who aspired to a higher social status. Not only was Elocution included in the curriculum of working class Institutes like that of Huddersfield, (T. Kelly, Adult Education in Great Britain, 1962, p. 128), but George Stephenson himself found his local dialect a great hindrance when speaking in public. For instance, when lecturing before the Newcastle Literary and Philosophical Society on his miners' safety lamp, 'Mr Stephenson was so diffident in manner and unpractised in speech, that he took with him his friend Mr Nicholas Wood to act as his interpreter'. (R. Spence Watson, The History of the Literary and Philosophical Society of Newcastle upon Tyne, 1793 - 1896, p. 147). Thus Elocution was an essential attribute for ambitious men from a working class background, and, to Armstrong's credit, he realised this.

By including subjects like Elocution, History and Geography at this early stage, the workers were evidently being educated not only as mechanics but as men. This was in line with Thomas Coates' recommendations that although a good deal of the instruction in the Mechanics' Institutes bore 'no relation to the practical arts, yet it has unquestionably contributed to the intellectual happiness of the mechanic'. (Thomas Coates, Report on the State of the Literary, Scientific and Mechanics' Institutions in England, 1841, p. 27).

Equally, James Hole argued that: 'Education is not an affair of childhood and youth, it is the business of the whole life. ---- What, then, is the instruction which the Mechanics' Institutes should offer to the working classes? The answer is two fold. There is the instruction which they should receive to fit them for the position of members of a civilised community, and there is an instruction specially adapted to their individual vocations'. (James Hole, An Essay on the History and Management of Literary, Scientific and Mechanics' Institutions, 1853, p. 44).

Unfortunately, this attitude was counter to that of many of the upper classes who considered the education of the lower classes as a dangerous means of raising them above their social station. Nonetheless, almost from the outset, hidden within the curriculum at Elswick was the ideology of self help, coupled with the promise of upward social mobility which was the reward for hard work and temperate living. It will be seen later that these attributes were upheld and encouraged by Armstrong because they matched so closely his own personal philosophy for life. Indeed, according to his speeches, (See Appendices IV and V), his aspirations for his workers, were in line with those of the most ambitious Mechanics' Institutes. For instance, John Godwin, a Bradford cloth merchant gave this view at the meeting of the Social Science Association in 1859: 'Those who have watched the Bradford Mechanics'

Institute are able to state that they have seen, year after year, an unbroken stream of youths, sons of working men, rising to positions of responsibility they never would have filled without its aid, and in many cases, entering upon and pursuing a successful middle class career by the habits, the knowledge and the connections acquired in this Institute'. (Quoted in J.F.C. Harrison Early Victorian Britain 1832-51, 1971, 1981 edition, p. 176).

The importance of literary as well as mechanical achievement was apparent not only in the name adopted by the Elswick Works' Literary and Mechanics' Institute but in the fact that, from the early days in School Street, the modest establishment had a reading room and library. Thus the founders recognised that easy access to reference books was essential to the workman's progress and his deeper understanding of his educational programme. This need was especially acute in the days before the general development of public libraries. The Minutes of Evidence of the Select Committee indicate that 'wherever they can get the means of having a library, (the people) take advantage of it'. (Report of the Select Committee on Public Libraries, paragraph 1236). Indeed, from its inception to its closure in the 1970s, the Elswick Mechanics' Institute appears to have upheld Coates' view that 'one of the most absolute requisites for creating and sustaining a love of knowledge is a good library'. (Coates, p. 50). This view was further endorsed by Hudson's remarks on the Newcastle Mechanics' Institute. 'The greatest feature in this Institution, which alone has secured its continued existence, is the library, stated by Dr Dibdin to be the very best, for its extent and kind, in England'. (Hudson, pp. 140-41).

The Rules of 1859 indicated that the Committee, who held regular monthly meetings, were empowered to elect one of their members to act as librarian. His responsibilities, like those prevailing today, included the control of the stock of books, the implementation of the rules for borrowing and the imposition of appropriate fines. Like many similar libraries of the time, lack of funds limited the purchase of books, so honorary membership of the Institute was given to those who subscribed '£5 or more in cash or books', with the proviso that novels were to be restricted by a vote at the General Meeting. (E.W.L.M.I. Papers). This approach is somewhat more flexible than that which prevailed elsewhere. Nonetheless, the Elswick Committee seemed to uphold the view expressed by Samuel Smiles when giving evidence before the Select Committee on Public Libraries, in May 1849. He indicated that, generally, in the Yorkshire Union of Mechanics' Institutes, books on all subjects - History, Political Economy 'and a very large proportion of works of fiction' were read. He then added that 'a taste for a better description of literature is evidently increasing (and the) number of issues of works on Mechanics, Philosophy, Chemistry and Science is on the increase --'. (Report of the Select Committee on Public Libraries, paragraph 1960)

In addition to the facilities of their Library, the mechanics at Elswick were able to purchase from the Institute 'books, instruments, drawing paper and other materials necessary for their studies by applying to the teachers of the classes'. (See Appendix III, Rule Number 15).

The future of the Institute was assured when the sons of the employees of the Works were admitted, on their parents' application, at the age of 12 years. Unfortunately, the presence of high spirited youngsters, released from the strictures of their daily work, caused breaches of discipline in Elswick as elsewhere. The Report of 1863 shows that although, in the main, the teachers were satisfied with their pupils' progress, the Committee issued the following reprimand: 'Bad conduct will not be tolerated --- and stringent regulations will be --- rigidly enforced on all those who mis-conduct themselves in the future'. (E.W.L.M.I. Papers).

The admission of juveniles, advantageous though that was for the future, did, in the short term, cause problems with discipline and a reappraisal of teaching methods, as other Institutes found. One solution was to separate the younger from the older students. W.H.J. Traice, a prominent member of the Yorkshire Union of Mechanics' Institutes, argued that: 'It is apt to be disagreeable and humiliating to the latter to sit on the same form with lads who may be their superiors in the studies of the class. Moreover, the discipline for juniors is not equally suitable for seniors and, indeed, the mode of instruction may often be modified advantageously. With the boys, the memory may often be largely employed without constant reference to reason. With those of mature years, the reason must constantly be brought to the aid of memory'. (Quoted in Tylecote, pp. 101-102).

Apart from the minor members, normal membership of the Elswick Institute was open to all employees of Armstrong's Works, provided a member of the Committee would nominate them and vouch for their good character. Additionally, non-members could attend individual classes provided they paid their tuition fees a quarter in advance. Failure to pay any fees resulted in expulsion.

On the whole, Elswick's fees appear to have been modest, since they were 6s. 6d. per annum compared with the average of 8s. 6d. at other Institutes. (Hemming, p. 19), and as high as 12/- per annum in 1825 in the Newcastle Institute. (L.J. Dyer, "Newcastle Mechanics' Institute," Part I, Adult Education, Vol. XXII, 1949-50, p. 122). Furthermore, they were collected fortnightly, which was an acceptable arrangement for wage earning men of modest means, especially if, as at Elswick, this was the usual practice of payment. Indeed, the fortnightly wage was customary in Scotland and the North of England. (M. and J.B. Jefferys, "The Wages, Hours and Trade Customs of the Skilled Engineer in 1861", The Economic History Review, Vol. XVII, Nos 1 and 2, 1947, p. 38).

Financial considerations in one form or another were major stumblingblocks in the way of many Mechanics' Institutes. The most acute problems were the provision of suitable premises, including lighting and heating, and the payment of teachers' and librarians' salaries, as, for instance, the members of the Newcastle Institute discovered. (Dyer, Pt I pp. 122-8 passim and Pt II pp. 205-6). Fortunately, owing to the generosity of Armstrong and the Directors of the Company, no such concerns marred Elswick's progress.

Whereas, originally, the workmen of Elswick met together 'for the purpose of mutual instruction', thus avoiding the payment of staff, as the Institute expanded, qualified teachers were engaged to conduct the various classes until, by 1859, a head teacher was not only in post, but was free to choose both the number of assistants he required and the appropriate methods of teaching. (E.W.L.M.I. Papers). Again this is an example of Armstrong's practice of choosing a man for a position and leaving him to act on his own initiative. Furthermore, this shows that, even at this early stage, the Institute was operating with the three most desirable forms of education in the Mechanics' Institutes - lectures, classes and the library.

How did these three agencies measure up to the educational requirements of the day and the needs of the students in question?

In view of Armstrong's own emphasis on class teaching (See Appendix V) James Hole's views on the subject are noteworthy. Hole, who for many years was Secretary of the Yorkshire Union of Mechanics' Institutes, claimed that this method showed the 'skill and energy' of the management of any Institute and its 'value as an educational agency'. Occasional lectures, he claimed, were limited in their worth since they could not convey much accurate or positive information. Similarly, the library, though a useful adjunct to the education of those who knew its potential, was of little value to the student whose reading skills were limited. Thus, he argued, uneqivocally: 'It is in the classes that we look for the remedy'. (Essay, p. 31).

The fact that Armstrong encouraged class teaching in preference to lectures suggests that either he was aware of current attitudes or that he was prepared to be advised by his men. Either way, the educational organisation at Elswick was in line with the most progressive Institutes of the time and so much in tune with Hole's recommendations as to pose the question: 'Had Armstrong read Hole's works?' The Essay on the History and Management of Literary, Scientific and Mechanics' Institutions was published in 1853, when the Elswick Institute was already operating, albeit in modest premises, and some ten years before Armstrong opened the new building. Nonetheless, as a man of education, culture and wide interests, who was showing increasing concern for the welfare of his men, it seems reasonable to suppose that he knew something of its contents.

According to Hole, 'The first essential of any improvement in the operation of our Mechanics' Institutes is the provision of properly qualified teachers. Without this condition, even the elementary instruction of our institutes cannot be supplied'. Moreover, 'properly qualified teachers can only be obtained by being properly paid. We have no objection to gratuitous teachers but they must always be in a subordinate capacity'. (Essay, p. 59). Again, these views were shared by Armstrong.

Hole further argued that 'next in importance to the teacher come the tools to work with'. These included a good reference library, class-room models and apparatus, a museum and a laboratory. Again, the organisation of Elswick showed how far Armstrong concurred with these views. The library and the classes have already been noted, and his support for a laboratory was in line with his own extensive experiments throughout his industrial career. Indeed, for many years the laboratory attached to the Elswick Mechanics' Institute, which was used by students from all parts of the district, was considered to be 'the largest and most efficient in the North of England'. (Newcastle Journal, 25th April, 1963). Associated as it was with a large engineering works, Elswick had one advantage, seldom enjoyed by other Mechanics' Institutes. The relationship between theory and practice, in the minds of the students, was both immediate and apparent. By contrast, Hole argued: 'Working men, really desirous of obtaining, in the Mechanics' Institute, a knowledge of the principles of their trade, seldom find that knowledge there'. (Essay, p. 60). No such criticism could be levelled at Elswick, where the men were daily applying the practical skills in the workshop which they had studied in theory in the classroom.

From his own experience as a non-trained engineer, Armstrong realised, at a very early stage, the need to relate theory to practice and the need for a scientific understanding of the underlying principles of engineering. All his research into hydraulics and armaments pointed to one conclusion - that theory and practice were so inter-related that the one could not exist without the other. Not only did he believe this, but he applied it, par excellence, at Elswick. When the Works' complex was complete, the factory, the Mechanics' Institute and the elementary schools were integral parts of the same unit, both in place and in purpose. While, of necessity, the schools must be studied in another context, the workshops and the Mechanics' Institute were, truly, 'Armstrong's of Elswick'. There was no dichotomy between the theory of the classroom and the practice of the factory floor. The men moved from one situation to the other as easily intellectually as they did physically. Few other engineering works - certainly in the North East - could claim such an advantage.

Meanwhile, from its modest inception in John Windlow's cottage, the Institute spent the next 15 years in the cottage in School Street, provided by the Company. When this accommodation, in turn, became inadequate, a more appropriate venue was sought. As a result of successful negotiations between the Committee and the Company, the Institute met, for the first time, in 1863, in the new building. This was to be its home for the remainder of its existence, until its demolition in the 1970s. (E.W.L.M.I. Papers).

The importance of this new development to the Elswick Works in general and to the Institute in particular can be assessed from the papers which were retrieved from the Foundation Stone in 1928, and from the few records of the opening ceremony which still remain. According to the parchment entitled: 'Elswick Engine Works' Literary and Mechanics' Institute Fourteenth Anniversary', the Foundation Stone was laid by Armstrong on 1st September 1862. The land was given by George Cruddas and the cost of the building was defrayed by Armstrong's Company.

The personal involvement of Armstrong at this crucial stage in the Institute's development is apparent from those contemporary records which still survive. At the previous annual meeting, a Committee member, James Rowell, had spoken of the inadequacies of the existing accommodation which he described as 'a small dwelling house near the Works'. He observed that its inconvenience had long been felt 'especially by those who attended various classes'. This was partly because the Library was now being used as a classroom, thus preventing members from 'enjoying the resources of the Institute to anything like the full extent'. (E.W.L.M.I. Papers). A delegation, including Rowell, met Armstrong to discuss further plans. Rowell, who was associated with the Works from the outset, eventually became manager of the Bridge Yard and of the Ordnance Forge. He died in 1886, after 40 years' service with the Firm. (A. Cochrane, 1909, p. 48). Thus, he was the type of person whose views would be valued alike by Armstrong and the men.

A contemporary account of these negotiations indicates that 'it had only to be mentioned to the distinguished head of the Firm for it to be immediately attended to'. (E.W.L.M.I. Papers). Even allowing for the loyal over-statement in that remark, the fact remains that Rowell's request received the same courteous and prompt attention that Windlow's had done over a decade earlier. Why, at this stage? In acceding so readily to the men's request, Armstrong was not merely being polite, but was acting with enlightened self interest. He was no longer the urbane provincial lawyer but a captain of industry; not only a shrewd business man but one who had seen his career and his name nullified. Now, with every means at his disposal, he was seeking retribution. He saw the Mechanics' Institute as part of that plan, and the men of Elswick as central to its success.

As part of his campaign, he began to appoint young men of talent to supervisory posts, including, among others, George Rendel, Percy

Westmacott and Captain Andrew Noble of the Royal Artillery, who was an expert in gunnery. Although there is no recorded evidence to substantiate this, it seems reasonable to suppose that he actively encouraged the development of the Institute so that it would become the training ground for his future foremen and managers. His speeches and those of the officials of the Institute seem to bear out this theory.

His business was expanding rapidly, especially when his supply of armaments to the Admiralty included the 110 pounder guns for H.M.S. Warrior. Built in 1860, this, as noted earlier, was Britain's first iron-clad battleship, described as the most revolutionary warship ever built. (McKenzie p. 72). Such a contract had great technical as well as economic significance for Elswick.

'War - especially that very commercially minded organisation the British Navy - contributed even more directly to technological innovation and industrialisation. Its demands were not negligible - Government contracts came in large blocks and had to be filled on time. It was worth a business man's while to introduce revolutionary methods to supply them'. (Hobsbawm, p. 50).

Armstrong did not intend to allow such a prestigious opportunity to escape him. Determined to vindicate his name after Woolwich, he proceeded to make Elswick a firm of world-wide renown, staffed by engineers of the highest calibre. Whereas, hitherto, craft skills in engineering had been paramount, Armstrong saw that, in future, engineers would have to be as competent theoretically and scientifically as they were practically. At this time, 'marine engineering and, to a lesser extent, locomotive engineering were highly skilled trades, employing the best craftsmen'. (Jefferys, p. 33). Thus, in supplying guns for the Navy, Armstrong was not only working in conjunction with the best engineering works in the region, but was in direct competition with them for first-rate engineers. What unique incentive could he offer them? Elswick and the Mechanics' Institute would combine to become a centre of technical excellence where the most promising apprentices would be trained not only as engineers but as future supervisors and managers.

The records show that the Company agreed to defray the expenses of erecting a large Mechanics' Institute on land near to the Works which George Cruddas, one of Armstrong's original partners, had presented for the purpose. The building was designed by John Dobson, the architect whose work had already made such a notable contribution to the development of the centre of Newcastle, including the Central Station. He was described by Rolt as being 'without doubt the greatest of railway architects, a man of rare talent and vision who combined architectural with engineering skill of the highest order'. (Rolt, p. 287). This appointment, in itself, shows the strategic importance of the Mechanics' Institute in Armstrong's plans for Elswick.

The dimensions of the building, which faced on to the famous Scotswood Road, were 74 feet long by 42 feet wide while the outside appearance was that of a 'handsome brick building ornamented with red brick and stone'. On the lower floor there were two large classrooms, a reading room and a library, while upstairs, a lecture room, running the entire length of the building, had accommodation for 400 - 500 people. In addition, there was a house for the caretaker as well as committee rooms and other offices. (E.W.L.M.I. Papers). The cost of the building , alone, was £2,000 at a time when labourers at the Works earned 15/- a week while fitters and turners earned up to 30/- per week, exclusive of Sundays. (Evening Chronicle, 8th June, 1962).

Armstrong, having agreed to finance the project, left the details of its erection to the Committee of the Institute who chose to employ a builder from nearby Blaydon. Armstrong contacted his partners, four of whom immediately donated £500 each towards the cost. (Vickers' News 26th February 1971). The problem of inadequate buildings is a recurring theme in the history of most Mechanics' Institutes, thus it was to Armstrong's credit, as well as to the Elswick Institute's financial and educational benefit, that he and his partners so readily agreed to defray the costs of the new building.

The ceremonies of laying the Foundation Stone and of opening the new building, in 1862 and 1863 respectively, were combined with the Institute's annual soirée. The keynote speeches made by Armstrong demonstrate the confidence he had in the Institute and its place in Elswick's future. Thus, they are vital to a deeper understanding of Armstrong's contribution to education.

The first ceremony began when the Institute's President, George Hutchinson, invited Armstrong to lay the Foundation Stone, and alluded to the fact that the occasion marked the fourteenth anniversary of the founding of the Institute. Armstrong had persuaded George Hutchinson to leave Watson's High Bridge Works in Newcastle, where he had been 'one of the leading men', to come to Elswick and work as his assistant. Hutchinson became Head of the Drawing Offices and, by 1859, was Works' Manager. He was, in fact, regarded as Armstrong's second in command. (A. Cochrane, 1909, p. 48).

Hutchinson praised 'the great and personal interest taken by (Armstrong) in working men, especially those employed in (his) extensive Works at Elswick, and more particularly in those who enrolled themselves as members of this Institute, so practically shown by doing them the favour of opening out (his) new Banqueting Hall at Jesmond (for their use). As proof of the great benefit that this Institute has already afforded to some of those who have become its members, it must be mentioned that there are young men who came to these Works with no other prospect before them but that of "earning their bread by the sweat of their brow" but who, having availed themselves of the instruction given in this institution, now hold respectable and responsible positions'. Hutchinson concluded with this tribute: 'Your compliance with our request will be seen as another proof of the deep interest you take in all matters affecting us'. (E.W.L.M.I. Papers).

Armstrong's reply was cordial, but succinct, since he reserved his main speech for the soirée which followed. Here, as principal speaker, he spoke of "the incalculable value" of Mechanics' Institutes generally, in "supplying the deficiencies of an imperfect education and in offering the means of intellectual cultivation". His views were similar to those advanced by Brougham and Birkbeck, in an earlier age, when he argued that "there is no difference in intellectual power between the working man and those who are placed in a higher sphere. The only difference is in the amount of knowledge and mental cultivation possessed by each". He upheld the purpose of the Mechanics' Institute in "supplying the means of acquiring knowledge and of cultivating the mind (and of extending) to all humble classes the means of advancing their condition". The middle class morality of the time, with its underlying desire for social order, was especially evident in Armstrong's observation that, irrespective of whether the Institutes succeeded in advancing the conditions of the working classes or not, "at all events -- they tend to make them more respectable and happier men". (See Appendix IV B).

He encouraged his workmen to greater endeavours by stressing the importance of social advancement not only through hard work but through association with more cultured members of society. He concluded with these words: "Although the working man has not the lever to cultivate his mind possessed by the wealthier man, he yet, with industry and ability, may cultivate himself with the assistance of Mechanics' Institutes and with the advantage of the intelligent society he will meet there, he may succeed in improving himself to a very great extent". (See Appendix IV B).

This speech is central to any assessment of Armstrong's contribution to popular education, since it underlines his personal belief in self advancement through diligent toil, enterprise and thrift, and the place of the Mechanics' Institutes in achieving that goal.

The speeches which followed, although somewhat in the nature of an anti-climax, are worthy of mention because they demonstrate the achievements of the Elswick Institute at that time.

The underlying theme of Victorian morality was apparent throughout George Hutchinson's speech. He recalled that when Armstrong had opened the Banqueting Hall at his home in Jesmond Dene, he had spoken of opportunities being provided "to give the men something better to do than to indulge in those grosser vices which workmen were liable to fall into". He reassured the management that the Institute Committee would 'certainly not allow anything like games of chance to be conducted in it' although something ought to be done 'by means of which men would be pleased as well as instructed'. He therefore suggested that, in addition to the normal curriculum of 'scientific lectures and other means of improving members', games like cricket, quoits and gymnastic exercises would be beneficial to the young people of the neighbourhood. He concluded with the pledge that it was not the function of the Institute 'to take the workman from his home, but rather to turn his feelings into such a channel as to lead him to take a greater interest in the comforts of his home and family'. (E.W.L.M.I. Papers).

The success of the first 14 years of the Institute was emphasised by James Rowell, whose negotiations with the management had now come to fruition. He expressed the hope that the improved accommodation would bring both increased membership and a higher level of educational attainment. He noted that the new building could accommodate four times the amount of work previously achieved and hoped that, with a work force at Elswick of between 2 and 3 thousand, a membership of 1,000 in the Institute would be possible. Like others that evening, he recalled that many young men were already occupying responsible positions both at Elswick and elsewhere who, but for the Institute, would have lacked the necessary means of advancement.

The Secretary, Mr Taylor, endorsed James Rowell's plea for increased membership when he indicated that there were only 220 students at the Institute, of whom 70 were minor members. Apparently, like similar associations, the numbers fluctuated, but were at their highest in the winter when the evening classes were in session. Nonetheless, the constraints of the existing premises had limited the numbers. As it was, the reading room was used as a classroom and could only be used for its original purpose on those evenings when books were being changed. In conclusion he spoke enthusiastically of the encouragement given by the Company in establishing new classes in mathematics and mechanical and freehand drawing, as well as in continuing to pay the teachers' salaries. This was a benefit which Elswick enjoyed, but which was all too often lacking in other Mechanics' Institutes.

The importance of the Institute, not only in the life of the Works but in the surrounding district is evident from the multiplicity of interests represented on the platform on this occasion. Those present included Dr Collingwood Bruce, who was the son of the founder of Bruce's Academy, and a Roman historian of outstanding scholarship. His personal interest in technical education led to his continuing association with the Elswick Mechanics' Institute, where he constantly praised the level of trust and concern for each other's welfare which was such a distinctive feature of the Elswick community. (E.W.L.M.I. Papers).

These two ceremonies coincided with the annual soirées which, until the opening of the new Institute building, were held in the Works. For many years the organisation of these events followed a set pattern. Sir William and Lady Armstrong presided and presented the prizes; a local dignitary made a speech emphasising the importance of education to the working man; the drawings and models of successful students were displayed and a musical entertainment was provided by the Works' Band and Glee Club. Even in 1862, the prizes ranged in value from 2 guineas for a first class prize in Mechanical Drawing to a modest 2s. 6d. for the second prize in the third class of Freehand Drawing.

Although, on 1st September, 1862, the Works were again open to the public, instead of inviting 4,000 people as in previous years, the Committee agreed to limit the number to about 1,000. In the event, this was to be the last of the titanic soirées which had become so significant a feature of both the Works and the Institute. Henceforth, because the venue was to be the upper hall in the new Institute building, this limited the attendance to 500.

The annual soirée was a regular feature of many Mechanics' Institutes though, numerically, not on such a large scale as those at Elswick in the 1850s. The aim of such gatherings at Elswick, as at many other Mechanics' Institutes, was to present prizes to successful students and to advertise the work of the Institute by an exhibition of models and drawings made in the classes. Functions with a similar purpose have continued at the Elswick Works until the present time. For example, two Open Evenings which, for attendance, must have rivalled the soirées of the last century, were held on successive nights in August 1977, to celebrate both the Queen's Silver Jubilee and the 130th anniversary of the opening of the Elswick Works.

The soirée of 1863, was held, for the first time, in the new building. Important though this development was, in educational terms, it was only one of several extensions taking place at Elswick at the time. As Cochrane has observed, '1863 was an important and critical year in our history, for it was then that the Ordnance Works ceased to be a Government Arsenal and were amalgamated with the Engine Works, so that the whole place made, as it were, a fresh start'. (A. Cochrane, 1909, p. 7). Thus, it is only when viewed in the context of his wider plans for Elswick that Armstrong's ambitions for the Institute can be fully realised.

At the opening ceremony, about 600 people assembled in the upper hall of the new building to witness the 'fresh start' of the Mechanics' Institute. The usual exhibition of students' work was mounted including, on this occasion, 'a collection of microscopes made by workmen connected with the Works, possessing great power of beauty and finish'. (E.W.L.M.I. Papers).

Again, Armstrong was the principal speaker. He briefly outlined the history of the Institute to date and spoke of the difficulties encountered by the Mechanics' Institutes in trying to popularise science. (See Appendix V). He thought that this might be because "science is not amusement, but positive work. It requires mental labour and it is perhaps too much to expect that men who are required to work hard with their hands should, at the same time, work hard with their heads". At this time, the men were working ten hours a day, six days a week. (Jefferys, p. 34). Nevertheless, he paid tribute to those whose determination, in the face of discouragement and adversity, enabled them to persevere and eventually to occupy responsible positions in industry and commerce. He further observed that institutions like Elswick would have served their purpose if they produced only a few such individuals since they, in turn, set an example to their fellows of the rewards of patience and diligence.

This was Armstrong's view of education. Since only a few could rise from the factory floor to supervisory positions, the means had to be provided for them to do so. It could be argued that he was an élitist rather than a social reformer, and, in our more egalitarian times, this particular view of self help has been criticised. 'A minority of exceptional working men could be relied upon to respond to this appeal, but for the vast numbers of the working classes, the suggestion of self help was simply advice to lift themselves up by their own boot straps'. (J.F.C. Harrison, "Adult Education and Self Help", B.J.E.S. Vol. VII, 1957, p. 49).

Armstrong continued his speech by listing those facilities for study which were available at Elswick. Even before the Institute moved to the new building, these included the library and the classes. Armstrong's support for class teaching was re-affirmed when he argued that: "the greatest feature of interest is the classes which have been maintained from the first for the instruction of boys and men. I need adduce no further proof of the success of the classes than the fact that out of 37 persons employed as draughtsmen, men and boys, in the drawing offices of Elswick Works, no less than 33 have been advanced from the workshops, and have derived their qualifications from the classes supported by this Institute". In his opinion, the success of the Institute was assured on the strength of the classes alone.

The subject of training in workshops or in classrooms was to become an important, sometimes acrimonious, debate in which Armstrong was to become increasingly involved at national level.

Just as Owen at New Lanark maintained that disciplined learning for the young should be accompanied by recreation in the form of dancing and games, so Armstrong maintained that it was "not necessary or desirable that the Mechanics' Institutes should be founded upon a purely scientific basis". He believed that: "a great object will be attained if salutary amusement for their leisure hours were afforded to working men". In his opinion, "working men require good and wholesome recreation of both body and mind". His later benefactions to Newcastle, in the form of land for recreation and public parks, were a practical testimony to his beliefs.

On the theme of self advancement, he used similar arguments to those he adopted on the previous occasion, namely that the uplift of the working man can be achieved as much by informally associating with more cultured minds through literature and conversation as by the more formal means of lectures and classes. "It is by means of books that working men can bring themselves into communion with the highly gifted cultivated minds, and they will derive instruction, refinement and amusement from doing so. It is in an institution like this, where a working man, surrounded by books of the best authors and in communion with the most respectable and most intellectual men of his own class, can best acquire those qualifications which will increase his happiness and exalt his nature".

Nor did he overlook the esteem in which the firm held such ideals. "The Elswick Company, impressed with these views and anxious to promote the mental cultivation and intellectual enjoyment of their workmen, have provided this spacious and convenient building, and I most sincerely hope that it will have the effect of inducing large numbers to avail themselves of the advantages presented to them, and I trust that it will form the commencement of a new era in the history of this institution". (E.W.L.M.I. Papers).

Other speakers included George Rendel who, when the Elswick Ordnance Company was created, became its general manager and a partner in the Company, while still only 26 years of age. (A. Cochrane, 1909, p. 83). He alluded to Armstrong's return to Elswick after resigning his appointment at Woolwich and observed that his interest in the Mechanics' Institute had not waned, despite his having devoted 'all his talents and nearly all his time' to the service of the Government.

Despite the confident hopes for the future, which were so eloquently expressed at the the ceremonies in question, this was a watershed, both for the Institute and for Armstrong. Henceforth neither would be limited by the parochial boundaries of Elswick of 1847. The Mechanics' Institute, freed from the constraints of either Windlow's cottage or the house in School Street, was now settled in a new building with a staff of qualified teachers. Taking every advantage of national developments in education, the Institute became a recognised centre for scientific study in the region. From here, in later years, young apprentices were eligible for Whitworth and other scholarships to Armstrong College. (E.W.L.M.I. Papers). Thereafter, with their qualifications validated by Durham University, they could occupy senior management positions on a global scale, as Armstrong had envisaged.

For his part, Armstrong was to become an international as well as a local personage. Increasingly, he became involved, not only in business affairs, but in the ever widening issues of scientific and technical education.

Armstrong's speeches at Elswick indicate that he upheld some, if not all, of the principles on which the Mechanics' Institutes were founded, especially 'the instruction of members in the Arts they practice, and in other branches of scientific and useful knowledge'. The original Mechanics' Institutes were designed to serve the needs of the many, (Tylecote, p. 89), but Armstrong argued that only a minority of exceptional working men were capable of combining the rigours of academic study with hard manual work. Thus he was prepared to support the Elswick Institute.

The Victorian virtues of hard work and self help were epitomised in Armstrong's personal life and were reiterated in his speeches at Elswick. In his view, self help combined opportunities for developing strength of character with social and economic benefits both for the individual and for the community. (See Appendices IV & V Speeches 1862-3 passim). The demands imposed by serious study in the scant leisure hours remaining at the end of the day's work were such as would deter all but the most dedicated. Thus, Armstrong realised the need to encourage the exceptional few who fulfilled his own motto: 'Perseverance generally prevails'. He did so with promises of promotion within the Company. Although the Elswick Mechanics' Institute was described as 'A testimony to his care and anxiety to throw open the portals of literature and science to the working classes', (E.W.L.M.I. Papers), the evidence would suggest that this was too broad a view. At that stage in his career, Armstrong was not concerned with the 'elevation of the whole working class' but with the well being of his own employees at Elswick. In particular, he was involved with the advancement, within the firm, of those 'clever and talented men' who availed themselves of the educational opportunities afforded to them at the Elswick Mechanics' Institute. This aspect of his character is important, since it could explain why, when he was so supportive of Elswick Mechanics' Institute, he gave little outward encouragement to Nicholas Wood and the North of England Institute of Mining Engineers in their quest to establish the College of Physical Science in Newcastle.

From 1863 onwards, the Company and the Mechanics' Institute continued to flourish, and Armstrong became an engineer of world renown. In consequence, his chairmanship of official Government enquiries, combined with his presidencies of the British Association and of various professional bodies, left him little time for personal involvement at Elswick. In characteristic fashion, having appointed his men, he left them to work unaided. It was this trust, as much as the men's ability, that established Elswick's name. A contemporary described 'that skilled labour (force) which, under the guidance of able administrators, has really made the reputation of our works'. (A. Cochrane, 1909, p. 44).

Despite his other commitments, Armstrong retained his fascination for mechanics and for scientific enquiry. For instance, when almost 70 years of age, he asked Henry Fee, the foreman of the Light Ordnance Department, to make 'a surface plate mounted so that it could be tilted about one edge and the angle of tilt measured'. After examining Fee's drawing, he asked 'for a steel cube to which small additional weights could be attached to one face'. Some days later, having made several modifications to the size of the cube, he returned to Fee and said: "It is all right".

The professional respect which Armstrong and his men had for each other is seen in Fee's reply. 'I knew you were doubting the laws of friction once again, but it's no use lending you my notes from the Elswick Schools'. (Anon, Elswick, 1847 - 1947, p. 10. In E.W.L.M.I. Papers).

Far from being anecdotal, this story illustrates the direct link between past and present. It connects the days when the first Elswick apprentices went to Windlow's cottage to be taught elementary mathematics and when Armstrong arrived at the Works in a pony-drawn phaeton, with to-day's apprentices who accept computerised technology and inter-planetary communication as the norm.

Henry Fee, like Windlow, took a deep personal interest in the apprentices in his charge. As a result, when he died in 1919, his colleagues established the Henry Fee Trust. Annually since then, the Henry Fee Memorial Trophy - a beautiful scale model of the British Army's standard 18-pounder field gun of the Great War - has been presented to the best apprentice of the year. The names engraved on the plinth constitute a distinguished roll of honour of engineers who have made the name of Elswick respected throughout the world.

Allowing for modern developments in educational and industrial practice, that tradition is maintained by the present firm of Vickers and their Apprentices' Training School, where the Henry Fee Memorial Trophy is still awarded.

Typical of an apprentice's career structure envisaged by Armstrong was that of Peter Muirhead. He joined the firm in 1871, during Armstrong's lifetime, as an apprentice engineer specialising in gun manufacture, and later he was acknowledged as an expert in his field. By 1910 he was Head Foreman at Elswick, and after holding a similar post at Coventry Ordnance Works, he returned in 1927 as Works Manager where he had the task of reconstructing and reorganising the Elswick Works. He remained in post after normal retiring age in order to supervise the production of guns and tanks for the Second World War but died in 1941. This again is a direct link between Armstrong and modern times, between the nineteenth century and the Second World War.

Meanwhile, the building which Armstrong opened in 1863 was to be the home of the Mechanics' Institute until its demolition in the 1970s. By that time, not only had the premises been vandalised on several occasions, but the economic recession of the time had drastically reduced the number of employees at the Works, with a consequent diminution of the membership of the Institute. In the context of modern educational opportunities, Armstrong's vision of the Mechanics' Institute no longer applied. The building then became a recreation centre and the Works' Library, although still designated as the Elswick Works' Literary and Mechanics' Institute. At a Committee Meeting on 15th January, 1971, it was reported that 85% of the membership had agreed to close the library and thus dissolve the Institute, in accordance with the original Rules. (Minutes of E.W.L.M.I, 5th October 1970 - 15th February 1971, passim. In E.W.L.M.I. Papers).

Just as its opening in 1863 represented innovation in technical education, so its demise in the dawn of the space age was inevitable as a new generation of Elswick engineers prepared to meet another exciting challenge of change.

Nevertheless, in the days before the State accepted responsibility for technical education and many industrialists regarded their employees merely as 'hands', Armstrong's initiative, in combining industrial and technical education on the same site, was revolutionary. His vision of Elswick as a centre of excellence for the training of engineers became a reality, through the twin agencies of the workshops and the Mechanics' Institute. When, in 1878, the Livery Companies of London set up a Committee to consider a scheme for technical education and the Government appointed a Royal Commission to enquire into Technical Education in 1884, Elswick was one of the centres under review. Thus its value, in the national context, can be objectively assessed.

CHAPTER VII.

ARMSTRONG AND THE WIDER SCIENTIFIC COMMUNITY.

After the protracted campaign of character assassination by Armstrong's rivals on the subject of breech loading and rifled ordnance, he would have been justified in returning to Elswick in 1863, thoroughly disillusioned and content to live out the rest of his days in peace and tranquillity among his own people, and those of similar interests and inclinations. For thirty years he had known nothing but success. From his junior partnership in Armorer Donkin's legal firm, and his early lectures to Newcastle Literary and Philosophical Society, when he was acknowledged as 'our talented young townsman', (Literary and Philosophical Society Papers, 23rd January, 1844), to his success as an engineer and captain of industry, honoured with the F.R.S., a knighthood, and, in 1862, with the Honorary LL.D. of Cambridge University. (D.N.B. sub Armstrong pp. 64 & 66).

With such an eminent career, and almost universal recognition, how did he react to failure? What challenges still remained? At 53 years of age, he could, with impunity, have made plans for an early retirement - but that was not in his nature. Perhaps in the dark days of disillusionment he considered such a proposition, especially when, returning to the peace and tranquillity of the Northumbrian countryside at Rothbury, he set himself the personally rewarding task of building a home worthy of his new position among the bleak hills and craggy eminences of his native county. Aptly named 'Cragside', it was to embody all Armstrong's beliefs. A centre for the advancement of the sciences of hydraulic engineering and electrical research, it was the first house in the world to be lit by hydro-electricity. This was installed by Armstrong and Swan, in November 1880, from a water driven generator in the grounds. (R.C. Chirnside, Sir Joseph Wilson Swan, F.R.S. p. 14). Nonetheless, it was, above all, a sanctuary where Armstrong could find repose from his active public life. As the carving above the fireplace in the dining room succinctly declares: 'East, West, Hame's Best'.

Thus, Armstrong's career did not rest solely on armaments. Indeed 'the view which regards Armstrong as merely the inventor of more efficient implements of carnage, does an injustice to one of the most remarkable men of our time'. (Dolman, 1897, p. 99). Nor was he allowed to retire from the world's stage. Greater challenges still called. Science, as he himself maintained, was his first love, and to science he, later, returned.

His research continued to be recognised through his nomination to committees at national as well as local level. One such appointment had come when his concern for the guns in the Crimea was, apparently, engaging all his powers. The Collieries Association were told, in 1854, that the Royal Navy disapproved of the use of coal from Hartley Colliery, in Northumberland, because it produced too much smoke. This not only prevented ship to ship signals being read, but indicated the location of the ships to the enemy. Before making a final decision, however, the Government took cognizance of a report published by Sir Henry de le Beche, the prime mover and first Principal of the Government School of Mines, founded in London on 6th November, 1851, and Dr Lyon Playfair, the School's lecturer in applied chemistry. (D.S.L.

Cardwell, The Organisation of Science in England, 1980, p. 87). Their Report concluded that coal from South Wales had 'an evaporative power far above that of the Hartley coals of this district'. (W.G. Armstrong, J.A. Longridge, and Thomas Richardson, Three Reports on the use of the Steam Coals of the Hartley District of Northumberland in Marine Boilers, 1858, p. 3).

Being prepared neither to accept this assessment, nor to lose such a lucrative contract, the Steam Collieries Association of Newcastle upon Tyne agreed to offer 'a prize of £500 for the best method of consuming the smoke of coal especially when used for marine multitubular boilers', and, in 1858, appointed an investigation team of 'three scientific gentlemen of this vicinity'. (Armstrong et al p. 3). Proof of Armstrong's national and regional standing in the scientific and engineering world is evident in his appointment to this team, along with such eminent men as Dr Thomas Richardson, Professor of Chemistry at Durham University and James Longridge, a member of the Council of the North of England Institute of Mining Engineers which was founded in 1852, within a year of the School of Mines in London.

Despite their other commitments - including Armstrong's involvement with rifled ordnance - these men conducted their investigations with such 'great care and minuteness' that, by January 1858, they had produced three Reports which not only demonstrated the best method of consuming the smoke of coal in marine boilers, and in the process named the prize winner, but called into question some of the findings of de la Beche and Playfair. In consequence, they recommended that a further enquiry was necessary into what had become a national rather than a parochial issue.

'In the course of the experiments it will be seen that there was also elicited a collateral result of great importance, not altogether expected by those to whom the conduct of these experiments was intrusted. This result was the superior heating and evaporative powers of the Hartley coals of the North of England as compared with the coal of South Wales, being in total contradiction to that arrived at by Sir H. de la Beche and Dr Lyon Playfair, which assigned to the coals of South Wales an evaporative value much above that of the Hartleys of this district. To the injustice of the preference thus groundlessly and fallaciously obtained for Welsh coal, it is trusted these experiments must ultimately put an end. They are not given to the reader as decisive of the question at issue, but as certainly demonstrating the justice and desirableness of a further stringent inquiry into a matter not interesting to the coal owners of the North of England only, but of great public importance as regards Her Majesty's steam navy as well as the mercantile steam navy of the country generally. (Armstrong et al p. 4).

Nor were they alone in their assessment of the Report of de la Beche and Playfair. Eminent scientists took up the challenge, including Dr Ure who, in his Chemical Dictionary, expressed his reservations. Equally, two engineers, Robert Armstrong and John Bourne, published a paper, in 1856, suggesting that the conclusions were merely the results of laboratory experiments, unsubstantiated by practical tests. 'However valuable as scientific facts such investigations may be, it must be said that the labours of the eminent men engaged have been of little use in improving or illustrating the actual practice of engineers'. (Quoted in Armstrong et al p. 4).

By contrast, Armstrong, Longridge and Richardson carried out extensive trials - some at Elswick - for which they built a multitubular boiler, similar to those used in naval an mercantile vessels, in which they burned Hartley and Welsh coals. The results aroused considerable press coverage, and engendered deep criticism of the original Report of de la Beche and Playfair. The first of the three Newcastle Reports, published on 25th August 1857, established the following facts:

1. Hartley coal could be used in ordinary multitubular marine boilers without producing any smoke, yet without loss of power or economy.
2. The coal would burn completely, and more water could be evaporated while no smoke was made than would be the case under the most severe firing conditions producing dense black smoke. Indeed, the

quantity of water evaporated from 1 pound of coal could be increased by as much as 17 to 20% when no smoke was made, with corresponding economic consequences. (Armstrong et al p. 7).

As well as substantiating the claim for Hartley coal, these experiments were used as a control against which to assess the work of the 103 candidates competing for the prize.

After the publication of the first Report, Playfair, in a letter to a professional journal paid tribute to the team's work. 'No better men than those engaged could have been selected to make the recent experiments at Newcastle; and so far as these are described, they appear to have been made carefully and with judgment'. (Journal of the Society of Arts, 9th October, 1857). Furthermore, he conceded that the multitubular boiler used in Newcastle was a precision instrument, and thus capable of greater accuracy than that used by de la Beche and himself. Indeed, he even had the courtesy to acknowledge two remarkable inaccuracies in the Report submitted to the Government, to which he was a signatory. First he admitted that the small Cornish boiler used by de la Beche and himself was not only incapable of giving absolute results, but was, in fact, 20% less accurate than a good Cornish boiler, and as much as 50% inferior to the multitubular boiler used by Armstrong and his colleagues. Additionally, Playfair admitted that: 'In the reports cited, we explained that we did not profess to give the absolute values of the coals tried, but only the relative values under like conditions of experiment'. (Journal of the Society of Arts, 9th October, 1857).

This being the case, why did the Government accept their findings, and why did they have to wait for the Newcastle team to prove their inaccuracy?

Other critics of the 'notorious Admiralty Report' soon added their voices to the argument. Among the most persistent was Lewis Thompson, M.R.C.S., who, having condemned the Report at its first publication, now maintained that 'the experimental results obtained by Messrs. Armstrong, Longridge and Richardson stand in glaring opposition to those of the "notorious Admiralty Report" which it is the object of Dr Playfair to defend. ---- It is now many years since the Admiralty Report made its appearance, and so great was the confidence of the public in its correctness, that it became forthwith a standard for settling the value of British Coals, not only in the Navy and throughout the country, but also throughout a great part of the civilised world. If therefore this report is erroneous and imperfect great indeed must be the mischief it has caused and is causing; and ---- gross is the injustice which has been inflicted upon the manufacturing and mining industry of the North of England'. (Quoted in Armstrong et al Appendix p. 30).

Having stated his case, Thompson then demanded a full enquiry into why such an erroneous report was allowed to be published in the first place and how it came to assume such importance as to be the yardstick against which any future decisions on coal were to be measured. He indicated that Sir Henry de la Beche had promised that 'the funds of the Museum of Economic Geology, aided by a sum of £600' would be adequate to start the enquiry. This being so, Thompson speculated whether de la Beche was ignorant of the limitations of the boiler or, if being aware, nonetheless continued with its use. He then required Playfair to answer the following question:

'When, and by whom was this defect of the boiler pointed out, and why was such an imperfect report allowed to be thrust before the Majesty of these realms in such a form as to cause it to be presented in the fulness of its unfitness to "both Houses of Parliament by Command of Her Majesty"?' (Quoted in Armstrong et al p. 30).

Meanwhile, as the debate on steam coals continued, Armstrong and his colleagues, having completed their task, duly presented their three

Reports to the Steam Collieries Association, who, in turn, transmitted them to the Admiralty, with the following rider. They expressed their dismay at 'the wrong that was done "under sanction of Government" by the earlier Report which, while enhancing the virtue of Welsh coal, was detrimental to that from Hartley'. In consequence, they averred, the Royal Navy and other agencies were obliged to use 'an inferior coal at higher cost, while a superior coal was unjustly excluded', and from which any smoke could be 'easily and economically consumed'. (Armstrong et al p. 66). For their part, Armstrong and his colleagues were in no doubt about the miscarriage of justice perpetrated by the publication of the earlier Reports.

'We are quite prepared to be met by the assertion that the alleged superiority of the Welsh coal does not rest upon the Reports of Dr Playfair and Sir H. de la Beche, but that the vast development of the trade is in itself a sufficient proof of the superior quality of this mineral. --- But beyond this, it was the Reports in question which first gave the Welsh coal its high character. It was the consequent extensive adoption of this coal by the steam navy and public companies which gave to this character the apparent sanction of practical experience. The figures of the Reports were implicitly believed in, although from the beginning there were many who doubted, but their opinions being attributed to interested motives, could carry no weight against government authority and government practice, and so a grievous error eventuated in a grievous injury both to your district and to the national interests. We trust that our labours will have the effect of dissipating this error and removing this injury ---- and, as we trust, restore (North country coal) to that high position as a steam fuel from which it ought never to have been displaced'. (Armstrong et al p. 28).

As a result of their exertions, Armstrong, Longridge and Richardson not only justified their appointment by vindicating the use of Hartley coal but, through their Reports, strengthened the case of the Northern coal owners who thereupon pressed for and, indeed, obtained a full inquiry into the relative heating capacity of the various types of British coal.

In view of Armstrong's concurrent involvement with rifled ordnance, could his implied criticism of the Establishment have rankled to such an extent as to lead, within two years of his being signatory to the Report on Steam Coals, to the vindictive character assassination which resulted in his resignation from his Government post at Woolwich and his untimely return to Elswick in 1863? No evidence has yet been found to substantiate this theory, but the timing of the two events is, nonetheless, remarkable.

The Reports on the use of Steam Coals could not have come at a more opportune moment for the North East collieries. Not only were the Royal Navy and the Mercantile Marine expanding in line with Britain's increasing responsibilities as a world power but, at local level, while the endeavours of Armstrong and his colleagues were being publicised, Charles Mark Palmer, the Jarrow ship-builder, built the steam-powered collier, "John Bowes", in 1858. With a capacity of 650 tons, and her high speed, she delivered in one week an amount of coal comparable to that of one sailing collier in two months. Without the Reports of Armstrong, Longridge and Richardson, Hartley would have permanently lost the lucrative naval contract to the Welsh coalfield; without the John Bowes, Tyneside would have lost the equally prestigious London market to the Midlands, from which conveying the heavy mineral traffic by rail was more convenient and considerably cheaper. (McKenzie, p. 67).

Meanwhile, important events were taking place at Elswick. As a result of official obstinacy and prejudice, the Government returned to muzzle loading guns, which they retained for the next fifteen years. This obduracy meant that the British not only lost their superiority in defensive artillery, but occupied a vulnerable position which they could ill afford either as an island race or as Empire builders and world traders. Naturally, this change in policy greatly reduced the number of Government orders placed with the Elswick Ordnance Company in 1862, and 'they cast the Company adrift entirely in 1863'. (A. Cochrane, 1900, p. 15). Evidence of this change of direction, in economic terms, can be seen in the orders given by the War Office which, between 1859 and 1863 amounted to Ł1,067,000, but fell dramatically to a mere Ł64,000 during the next fifteen years.

Connections with the Ordnance Company were virtually terminated, yet it is difficult to explain, in rational terms, why Armstrong's considerable expertise and the vast resources at Elswick should be thus ostracised, while so many of his ideas on ordnance were still being practised in Government factories. In the event, a decade and a half would pass before the gunnery experts at Elswick again succeeded in persuading a reluctant Government to adopt their ideas which, with appropriate modifications, set the pattern for ordnance on a global scale. (A. Cochrane, 1900, p. 16).

The Government's reactionary policy led to a massive rationalisation of the factories at Elswick. Although restitution amounting to Ł65,000 was paid by the War Office, this did not really compensate the Elswick firm for loss of contracts. From being the leading supplier of heavy ordnance to the Armed Services, Elswick was now left to its own devices. Fortunately, Armstrong's own resiliance and that of his capable young managers helped the firm to ride the storm, although the hopelessness of the situation, in the short term, is seen in Cochrane's own description:

'The year 1863 was certainly the most critical in the annals of the firm. The absolute stoppage of orders threw a quantity of valuable machinery idle and the metier of the Ordnance Company as a factory for Government supply was gone. To make matters worse, the great and unnecessary delay on the part of the Government in releasing the firm from (that) side of the agreement, --- which limited their manufacture of guns to England alone, prevented Elswick accepting foreign orders'. (A. Cochrane, 1900, p. 71).

Having resigned from his Government appointment on 5th February 1863, Armstrong returned to Elswick. Within a year, the original Engine Works and the nearby Ordnance Company amalgamated, and blast furnaces were added to the enterprise which was known thereafter as Sir W.G. Armstrong and Company. Two of the surviving partners of the initial Elswick Engine Works - Armstrong and George Cruddas - were joined by Captain Andrew Noble, Percy Westmacott and William Cruddas, with Stuart Rendel being appointed later. (A. Cochrane, 1900, p. 72). Unfortunately, as Cochrane observed, the new firm was 'equipped with much machinery and few orders', due to the Government's intransigence whereby, having ostracised Elswick, it would not rescind the agreement to supply armaments solely to the British Armed Services. This impasse meant a delay in orders, even to the extent of supplying British merchant ships with 'a gun or two as protection against pirates'. (A. Cochrane, 1909, p. 88). After protracted correspondence between 1862, when the War Office decision was first announced, and the end of 1863, the Government finally terminated the contract. Thereupon, the firm accepted not only non-Government British orders, but began the extensive and lucrative ordnance trade with foreign Governments which became such an important feature of its subsequent history.

Although 1863 dawned as such a melancholy year for Armstrong, it was, ultimately, to prove his annus mirabilis. Three important issues helped to make it so. First he saw his Works at Elswick, now untramelled by Government strictures, set on a course of expansion which, aided by the undivided commitment of both management and men, was to continue almost unbroken throughout Armstrong's life and, indeed, until the world wide recession of the 1920s. Furthermore, 1863 saw the early development of his estate at Cragside. Moreover, despite its gloomy forebodings and his own, understandable, sense of failure, 1863 gave Armstrong what he described as "the greatest honour of my life", when, in the ambience of the wider scientific community, the British Association for the Advancement of Science accorded him their Presidency when they met in Newcastle, for only the second time.

During its formative years, the British Association tended to choose as their President a notable person from the locality of their meeting, rather than one eminent in science. Gradually, the presidency became recognised as one of the highest honours accorded by the scientific world. Thereupon, it became the practice for the local dignitaries to welcome the President as a distinguished visitor, rather than for him to welcome the Association to his own region. (Howarth, p. 107). In the case of Armstrong, the two rôles happily combined.

For his part, Armstrong regarded this appointment as no sinecure. Not only did it restore him to his wonted place as one of the country's leading scientists and industrialists, and enabled him again to associate with men of like mind, but it gave him the opportunity to expound his own theories still further. The deliberations of the conference were published under the title of: <u>The Industrial Resources of the Tyne, Wear and Tees</u> and, from the outset, acknowledged Armstrong's rôle in both the region's and the country's development.

'This locality is peculiarly rich in (manufactures), inasmuch as it is the birthplace of the Locomotive and the Railway system; it has witnessed the introduction of the Glass, Alum and Soda trades, which were all first commenced in this district; it was here that Stephenson invented his Safety-lamp, and Pattinson the Desilverising of Lead, whilst Buddle perfected the Furnace Ventilation of Mines; and lastly, the country owes its most valuable arm of defence to the ingenuity of Sir W.G. Armstrong, of Elswick. ----- The district can also point to the celebrated engineering and shipbuilding factories of Stephenson, Hawthorn, Armstrong, Palmer, Bell and many others, whose locomotives and engines, hydraulic machinery, guns and ships, have acquired a European reputation'. (Report of British Association, Newcastle, 1863 Preface, p. iii and iv).

Further public acknowledgement of Armstrong's rôle, albeit indirectly, had come during the visit to Newcastle, in the previous year, of W.E. Gladstone, then Chancellor of the Exchequer.

Not only was Armstrong invited to attend the banquet held for Gladstone in the Town Hall, Newcastle, but he proposed one of the main toasts of the evening. (Newcastle Daily Journal, 8th October, 1862). The following day, Gladstone sailed from Newcastle Quay to the mouth of the Tyne and was received en route by local civic diginitaries and representatives of commercial and industrial life. The secretary of the Chamber of Trade at Tynemouth reminded the Chancellor that on his recent journey he would have seen:

> 'a river not only remarkable for its commercial importance but ----for its historical associations. It has borne the triremes of Rome and the vessels of the Danes. On its banks are still the remains of the Roman Wall and the ruins of priories and monasteries. ----- You have viewed commercial and manufacturing activity on both banks of the Tyne; our vast chemical laboratories; our iron forges, where the mighty hammer beats night and day; our shipbuilding yards where, almost weekly, vessels are launched for the most distant quarters of the globe; these and the vast fleets of ships to be seen in our river --- (are) the proof and signs of enterprise and activity which contribute not a little to the national prosperity and the power of Great Britain'. (Newcastle Daily Journal, 9th October, 1862).

Both the speaker and Gladstone praised the work of the Tyne Improvement Commissioners in building two substantial piers at the mouth of the river, and in constructing the new deep water docks nearby. These facilities not only enhanced the commercial potential of the area, in general, but extended the scope of the coal trade in particular. In these developments, William Armstrong, senior, both as Chairman of the River Committee for many years, and as Mayor of Newcastle between 1850 and 1851, had played a notable part. Nonetheless, it is in the context of the engineering and industrial life of the river that his son's name is remembered, and his was one of several honoured, by implication, in Gladstone's speech at South Shields:

'I know not where to seek, even in this busy country, a spot or district in which we perceive so extraordinary and multifarious a combination of the various great branches of mining, manufacturing, trading and shipbuilding industry, and I greatly doubt whether the like can be shown, not only within the limits of this land, but upon the whole surface of the globe'. (Newcastle Daily Journal, 9th October, 1862)

Over the years, the Presidential Address to the British Association evolved from an exchange of courtesies to a retrospective overview of the previous year and a prospective survey of the current meeting. Gradually the pattern emerged, which it still retains, whereby it became an annual public pronouncement of scientific progress. In 1868, the President, Sir Joseph Hooper, suggested that it should be 'either a scientific tour de force, or a resumé of one or more important branches of science'. (Howarth, p. 108). By this, Howarth suggests, he probably meant that the speech could be used by scientists to advance their theories on everyday subjects, which would then become the subject of wider debate. As an example, he cites Armstrong whose wide ranging speech included, among other topics, metrication, the duration of Britain's coalfields, and alternative sources of energy.

In his Presidential address, which ranks as 'one of the best he ever delivered', (Dougan, p. 97), Armstrong alluded to the fact that a quarter of a century had elapsed since the British Association had assembled in the town. He reminded his audience that in no equivalent period had there been comparable progress in either physical knowledge or mechanical science, especially in the application of steam power to transport. In this sphere alone, he claimed: "the progress made has no parallel in history". (Armstrong's Presidential Address, Report of British Association, Newcastle, 1863, p. xv). The railways, he reflected, were in their infancy, in 1838, while the problem of crossing the Atlantic by steamship had been solved only in the previous year. Since then, railways had crossed every continent, and steamships every ocean. At that point, with ill-concealed local pride, he recalled that: "the locality in which we hold our present meeting is the birthplace of railways, and the coal mines of this district have contributed more largely than any others to supply the motive power by which steam communication by land and water has been established on so gigantic a scale". (Presidential Address, p. xvi). Whereas, like other speakers at the conference, Armstrong paid due deference to the work of George and Robert Stephenson, remarkably, he did not allude to the fact that both had died since the Association last met in Newcastle - George Stephenson in 1848, and Robert in 1856, only a few months after attending the banquet held in Newcastle to honour Sir William's knighthood.

Although Armstrong applauded the country's recent industrial achievements, he was more concerned with the future than the past. Indeed, most of his speech would not be inappropriate if delivered in a similar assembly by one of his modern counterparts. For instance, in order to illustrate the remarkably modern concept of the direct correlation between environment and intellectual development, Armstrong drew a parallel between the ability of plants to survive in a particular location, through the process of natural selection, and man's ability to apply his inventive genius to develop an industrial infrastructure appropriate to his needs.

"In glancing at the history of the railways, we may observe how promptly the inventive faculty of man supplies the device which the circumstances of the moment require. No sooner is a road formed fit for wheeled carriages to pass along, than the cart takes the place of the pack-saddle; no sooner is the wooden railway provided than the wagon is substituted for the cart, and no sooner is an iron railway formed, capable of carrying heavy loads, than the locomotive engine is found ready to commence its career. As in the vegetable kingdom fit conditions of soil and climate quickly cause the appearance of suitable plants, so in the intellectual world, fitness of time and circumstance promptly calls forth appropriate devices. The seeds of invention exist, as it were, in the air, ready to germinate whenever suitable conditions arise, and no legislative interference is needed to ensure their growth in the proper season". (Presidential Address, pp. xvi and xvii).

Although Armstrong observed that the coalfields of the region, would form part of the deliberations of the conference, either as a discrete entity or in conjunction with the railways, other, though not unrelated issues, dominated his Presidential Address. Remarkably, these matters are still the legitimate concern of scientists, economists and industrialists to-day.

Noting that "the philosophical mind of George Stephenson, unaided by theoretical knowledge, rightly saw that coal was the embodiment of power from the sun", Armstrong advanced the hypothesis, so often expounded to-day, that this country's prosperity ultimately rests on an abundant supply of cheap coal. He then issued a dire warning that already more of this precious mineral had been raised from this country's mines than had been extracted by the rest of the entire world, and, as a result, we should soon be faced with increasing costs for an inferior product. According to the statistics of Mr Hunt of the Mining Record Office, the amount of coal mined in the United Kingdom, in 1861, was 86 million tons, and the average annual increase in the eight preceding years was 2,750, 000 tons. (Presidential Address, p. xx).

How long, reflected Armstrong, would our coal supply last, if this rate of extraction were to continue? Working on the premise of an available coal stock of 80,000 million tons, and given the present rate of consumption, the entire quantity of available coal would, he averred, be exhausted in 930 years, but with a projected annual increase of 2,750,000 tons, it would last only 212 years. "It is clear", he observed, "that long before complete exhaustion takes place, England will have ceased to be a coal producing country on an extensive scale". Then, with almost prophetic insight, he suggested that other countries, especially the United States of America which possessed almost 40 times our coal supplies, would still be working their readily accessible seams, at an economic rate, and would relieve the British coalfields of their existing markets. Thus, he argued, the dominant issue was not the lifespan of our coalfields, per se, but for how long they would be economically viable so that our manufacturing industry could maintain its supremacy in the world's markets.

In the Northumberland and Durham coalfield, Armstrong observed, it was generally acknowledged that the principal seams would be exhausted within 200 years, but he warned that they would be viable for only half that time if, in order to meet the unnecessarily wasteful demands of domestic and industrial users, production continued on its present course. Even the most economical steam engine, he averred, was using thirty times the amount of coal needed to drive a perfectly efficient one, and he challenged the mechanical engineers to apply themselves to this problem. Nevertheless, he did admit that the future was not unmitigated gloom. Research into the efficient application of heat was already being advanced, due to the work of men like Siemens, supported by the British Association, and scientists were already heralding the demise of the inefficient steam engine and were forecasting that, before the supply of coal was exhausted, another motive power would take its place. In this context, Armstrong noted, electricity was the one most widely quoted.

The generation of electricity by hydro power naturally claimed Armstrong's attention and, in demonstrating the advantages of using artificial lakes in elevated situations, he made reference to the water works at Greenock where the reservoirs were situated at 512 feet above the River Clyde. These, he claimed, gave a daily yield of nearly 100,000 tons of water from the rainfall over a catchment area of 5,000 acres. The power obtainable from such a head of water was, he maintained, equivalent to that of a steam engine of 2,000 horse power. Impressive though that hydraulic capacity was, it paled into insignificance when compared with the potential of places in Switzerland and elsewhere, where the water from the natural lakes descend from great heights either by swift flowing rivers or waterfalls.

These torrents, he declared, aided by artificial controls to impound the surplus water and regulate the supply, had a potential yield of thousands of horse power. Not only would such developments alleviate the possible shortage of coal, but, he continued, "there is at least one great river in the whole world which, in a single purge, developes sufficient power to carry on all the manufacturing operations of mankind if concentrated in its neighbourhood". (Presidential Address, p. xxiv). He then observed that, hitherto, industrial populations had not extended to such regions, but he looked forward to the time when these natural sources of power would be used to their full capacity.

In a further reference to coal, he reminded his audience of its use in smelting, where the need for greater economy was all too apparent, especially when most of the heat escaped up the chimney. Naturally, in the light of his recent researches, he equally deplored the unnecessary production of smoke from inefficient furnaces. "Clouds of powdered carbon envelop our manufacturing towns, and gases which ought to be completely oxygenised in the fire pass into the air with two thirds of their heating power undeveloped". (Presidential Address, p. xxv). In a reference to the experiments of 1857 and 58, he declared that: "I can state with perfect confidence that, so far as the raising of steam is concerned, the production of smoke is unnecessary and inexcusable". (Presidential Address, p. xxvi). Furthermore, he reminded his audience that those experiments had proved that, with proper management, the emission of smoke could not only be avoided, but its prevention would use less fuel and would increase the evaporative power of the boilers.

Another area of concern was in the consumption of domestic coal, which, on current figures, was around 29 million tons in Great Britain alone. In examples reminiscent of many of our modern advocates of domestic energy saving devices, either for culinary or space heating purposes, Armstrong criticised the wasteful use of fuel in these specific areas. A pound of coal, he noted, would evaporate 10 pounds or a gallon of water, if used in a well constructed boiler. Yet if this result was compared with the insignificant amount of steam produced in a kettle by a pound of coal burned in an ordinary kitchen grate, the enormous wastage of energy in the daily household routine is axiomatic. Similarly, in domestic heating, the coal consumption of an open fire is about five times that needed to produce a comparable amount of heat from a more efficient stove. By applying the principles of radiation and convection, he maintained, the vast amount of heat which currently escapes up the chimney, could be effectively utilised, and, without sacrificing the pleasure of a coal fire, a more efficient heating system would result.

Although, as he apologetically claimed, these homely considerations seemed unworthy of his audience, nonetheless, he justified their inclusion on the grounds that such reprehensible waste, exceeding as it did the contemporary rate of income tax, could be rectified by the application of proven scientific principles, and could, with impunity, engage the attention of some members of his audience. Considering the topicality of the subject in the modern world, Armstrong's somewhat diffident presentation of the subject is a source of regret. Nevertheless, to his credit, the issue was not beneath his notice, even though, to some of his audience, it was of only marginal importance.

The introduction of the Davy-lamp then claimed his attention. Not, he regretted, that it had greatly reduced the number of mining accidents but it had enabled mines to be worked which, because of their explosive tendencies, would have been impracticable. Miners were now venturing into more dangerous seams and, in consequence, into more explosive situations than would otherwise have been possible. Nevertheless, he believed that the Davy-lamp was a fine example of sound scientific principles applied to practical purposes which, with correct usage, was highly efficient.

Unfortunately, in mines where these lamps were distributed to hundreds of men, not all of whom were as diligent as the situation required, it followed that, through the negligence of the few, accidents could and did occur. This was still the case even in mines where safety standards were high, although, fortunately, such situations were decreasing both in proportion to the tonnage of coal worked, and as a percentage of the number of miners employed.

The importance of keeping accurate records did not escape his notice. He recalled that the matter was raised by Thomas Sopwith at the previous meeting of the British Association in Newcastle in 1838, which resulted in the establishment of the Mining Records Office. Although plans of abandoned mines were stored there, pending decisions on their future, he felt that more action was required. Many of the inferior coal seams could become economically viable only if worked alongside of those of superior quality, but their working would never again be praticable if they were abandoned, until the superior seams were exhausted.

Then, making a proposition which was only fully realised almost a century later, he observed that, although coal was then private property, its duration was of national concern. Thus, he averred, Government legislation was essential in ensuring modes of working practice in line with the long-term national interest. Before the Government could take effective control, he believed that it would be necessary to conduct a complete survey of every coalfield, and to locate the resultant plans, sections and reports at the Mining Records Office for access by Government and public alike. (Presidential Address, pp. xxviii - xxx).

Before dismissing the subject of coal, Armstrong referred to Berthelot's recent discovery of carburetted hydrogen which gave twice the illumination of ordinary coal-gas. Similar work by other scientists seemed to ensure the practicability of the new gas for lighting purposes. Thus, Armstong observed: "the discoveries which, in the first instance, interest the philosopher only, almost invariably initiate a rapid series of steps leading to results of great practical importance to mankind". (Presidential Address, p. xxxi).

After outlining researches both into the composition of the sun and as a source of power, he emphasised the importance of such information in the extension of our knowledge of heat, light, magnetism and electricity. The dynamical theory of heat, in turn, led him to make passing reference to the explosive power of gunpowder, and thence to the science of gunnery and the study of the velocity of projectiles.

Two further items which are still relevant to modern society were his references to metrication and the effective transmission of information. Indeed, in words which could well be used by any modern scientist or politician, he claimed that: "The facility now given to the transmission of intelligence and the interchange of thought is one of the most remarkable features of the present age". (Presidential Address, p. xxxvii). He went on to consider the universal availability of the postal service; of the cheapness of paper and printed matter, and of the electric telegraph which could transmit information not only between nations and towns, but also, because of the work of Professor Wheatstone and others, to the individual householders. All these agencies, he argued, "contribute to aid that commerce of ideas by which wealth and knowledge are augmented". (Presidential Address, p. xxxviii).

Although mental communication was thus facilitated by these new developments, the basic art of written communication appeared to have made less progress. "It seems strange", he noted, "that while we actually possess a system of shorthand by which words can be recorded as rapidly as they can be spoken, we should persist in writing a slow and laborious longhand". Whereas this could not be rectified in those adults who were set in their ways, the future generation should be taught to use a speedier form of writing more in line with mental communication. This, he felt, could be achieved by using symbols for the most common syllables in everyday use. As this matter involved both social and physical scientists, alike Armstrong did not press his case, but rather raised it as a point for future discussion. (Presidential Address, p. xxxviii).

In arguments similar to those used a century later, Armstrong raised another issue which spanned the social and physical sciences, and which, he felt, was worthy of a deeper consideration. This was the contentious matter of weights and measures. Laying aside the respective merits of the decimal and duodecimal systems, he maintained that the fundamental problem was the universal acceptance of a uniform system of measurements. Scientific progress, he claimed, was impeded by lack of standardisation. Valuable knowledge gained in one country was lost to another because of the time and effort needed to convert the measurements from one scale to another. Commerce, too, was impeded both by a lack of knowledge of the scales involved and by resultant errors. He regretted that two standards of measurement so similar as the English yard and the French metre should not be completely standardised. The metric system, he suggested, having been adopted by other nations, had the best claim to becoming universally accepted. Thus, he argued, in the search for uniformity, England must conform with France. The scheme could be introduced informally rather than through legislation, for if scientific literature habitually used metric terminology, it would automatically pass into commercial life and wider usage. He then spoke from personal experience at Elswick, where he found that decimal measurement was superior in those forms of mechanical construction where the highest standards of accuracy were required. In Elswick and other similarly large establishments, the inch was adopted as the standard unit but the fractional parts were expressed as decimals. He argued that greater precision in workmanship had been achieved without undue difficulty in training the men to use this method. Nevertheless, he considered that the inch was too small an entity and suggested that the metre should, as a matter of urgency, become the standard unit of measurement. Equally, he claimed that the thermometric scale, which "was originally founded in error (and) is most inconvenient in division" ought to be replaced by the Centigrade scale. He proposed that the British Association should adopt the metric system and the Centigrade scale and use them in their future published proceedings. With almost prophetic insight, he suggested that this would expedite the universal adoption of "the French standards in this country which, sooner or later, will inevitably take place".

After making passing references to the work of the Royal Geographical Society's expedition to locate the source of the Nile, and to Darwin's theory of evolution, he ended his address with words which could, with impunity, have been his own epitaph:

> "The tendency of progress is to quicken progress, because every acquisition in science is so much vantage ground for fresh attainment. We may expect, therefore, to increase our speed as we struggle forward; but however high we climb in the pursuit of knowledge we shall still see heights above us, and the more we extend our view, the more conscious we shall be of the immensity which lies beyond". (Presidential Address, p. xlii).

The 'thunderous applause' which greeted Armstrong's speech heralded the dawn of a new era for both him and the Elswick Works. No longer would he fight for recognition of his ideas, only to see them, and his reputation, torn to shreds. Now, he recognised that his future lay among the scientists and the researchers, or amidst the incisiveness of academic debate, rather than in the gladiatorial conflict of the business and industrial world or the political arena. The men of ideas rather than the men of action, from henceforth, were to be his people. Increasingly, he withdrew from active involvement at Elswick and concentrated on his other interests. The future of the Works, he now realised, lay in winning foreign orders, but, according to Stuart Rendel, he 'looked at the matter with much indifference'. (Hamer, p. 277).

If the same commitment and determination had been present as that which produced the hydraulic cranes for Newcastle Quay, or his Number One Gun, valuable contracts could have been won, from both sides, early in the American Civil War. In the event, Stuart Rendel, who had pleaded Armstrong's case before the Committee on Rifled Ordnance, now had the thankless task of persuading Armstrong, himself, to sell his armaments abroad, before foreign powers, clamouring for such weapons, began to buy from Elswick's rivals. Once this happened, Rendel argued, others would 'usurp his place', and the British Government, having seen the merits of these other systems, would, only reluctantly, place future orders at Elswick. (Hamer, pp. 276 - 277). Although apparently unwilling to agree with Rendel's argument, he did concede that: "If these are your opinions, you are perfectly at liberty to try to give them effect, and if you can obtain any orders for Elswick, by all means do so". (Quoted by Rendel in Hamer, p. 277). At this stage, Rendel was not actually an employee of the firm, so Armstrong offered him a 5% commission on any contracts he obtained. The first foreign orders accepted by Elswick were, in fact, to supply small quantities of arms to the opposing forces in the American Civil War. These, according to Rendel, were negotiated 'with great secrecy' and, through his personal intervention, necessitated clandestine meetings with bankers and military agents in Paris and elsewhere. (Hamer, pp. 277-278).

Rendel's personal acquaintance with Captain - later Admiral and Senator - Albini who, acting as Italian Naval Attaché, was then in Belgium negotiating the sale of his own rifle, resulted in Elswick's first order for guns for the Italian Government. Similarly, through his college friend, the future Lord Goschen, Rendel learned that the Khedive of Egypt was, secretly, sending a personal friend to Europe to negotiate arms contracts. In due course, according to Rendel: 'Efflatoun Pasha placed himself entirely in the hands of the Elswick firm, and for some time, I was the intermediary through whom his very important orders for guns were placed. Later on, he visited Elswick itself, and became greatly attached to Sir Andrew Noble'. (Hamer, pp. 278 - 279).

The new Armstrong and the new Elswick are implicit in that quotation. At 53 years of age, the erstwhile lawyer, inventor and businessman set course on yet another new career. Already a national figure, he was now to be increasingly invited to pronounce on major issues or to give evidence before Select Committees. Elswick and its fortunes were, apparently, safe in the hands of his young appointees - the Rendels, Westmacott, Noble and the rest. Their loyalty to the firm, if not always to himself, was absolute and he could now withdraw, if not retire, from his management of the firm, where, through his enforced absence in London, he was no longer the familiar figure of old. As Dougan observes: 'Instead of the central driving force, working with single minded dedication late into the night, he became the judicious Committee chairman. He still tended to take the important decisions, but he no longer made the physical commitment he had once done, or that Andrew Noble was now doing and was to do all his life'. (Dougan, p. 99).

The scope of Armstrong's activities continued to widen. In 1860, he was appointed President of the Newcastle Literary and Philosophical Society - an office which he held for the remainder of his life - and in 1862-63, he was elected to the Council of the Royal Society. Armstrong's other new interests included the exhaustion of the coal supplies, and his involvement in this issue, at national level, was brought about on two counts. When the Steam Collieries Association presented the report on Steam Coals to the Admiralty, they emphasised the need for a Royal Commission to study the British coal supplies. Furthermore, when Armstrong made his Presidential Address to the British Association, he attacked the thorny issues of the wastage of fuel by industrial and domestic users and the consequent exhaustion of our coal supplies. In view of Armstrong's national reputation, and in light of his recent involvement with the Hartley Steam Coals Report and with the British

Association, his plea could not be ignored. In consequence, the Government set up a Royal Commission, in 1866, under the Chairmanship of the Duke of Argyll. By the time the Report was issued in 1871, Armstrong had been both a member of the Commission and one of its principal witnesses. Indeed, it has been claimed that 'his evidence was among the most valuable information collected by it'. (D.N.B. sub Armstrong, p. 67).

In view of his long experience in different branches of metallurgy, Armstrong was asked by the Chairman to give his views on the wastage of coal during combustion. His reply gives a useful personal appraisal of his expertise:

> "I do not consider that my experience is at all considerable in matters connected with metallurgy. It is chiefly as an engineer that I may be considered to speak with any sort of authority on matters relating to the combustion of coal, though of course, I entertain general ideas on the whole subject". (Report of the Commission to Inquire into the several matters relative to Coal in the United Kingdom, 1871. Question 224).

Thereupon, he suggested that, in general, the subject under discussion could be considered under three headings: the consumption of coal for domestic use, for motive power and for manufacturing purposes. Furthermore, he estimated that the amount of coal consumed by each category would be roughly equal, and he considered that not only was the present wastage excessive, but could, to a large extent, be remedied. The extravagant waste of fuel in what he described as "the old fashioned open kitchen fire, still in general use for cooking" was all too apparent. Reiterating some of his previous arguments, he reminded his audience that 1 pound of coal, burned in a well constructed steam boiler, would evaporate 10 pounds of water, but when burned in an open fire, the waste was excessive. These defects, he argued, were well known, and could easily be rectified by a greater use of the economical kitchen ranges, which, though in plentiful supply, were largely ignored by the general public. Returning to some of his proposals made to the British Association, he argued that warming the houses by open fires using radiant heat was wasteful. Indeed, he estimated that the amount of heat required to raise the temperature in any given area was about 5 times greater with an open fire than with a properly constructed stove.

The solution, he suggested, lay in the use of convection rather than radiation. However, the objection to that system was that the air in the room was said to be excessively stuffy. This, he suggested, was due to the current state of technical development, whereby the only stoves available were such that their limited size caused over heating. "If that were obviated by a larger surface at a lower temperature," he declared, "it would be quite practicable to have a perfectly agreeable heat with a fraction of the quantity of fuel which is now used". (Report, Coal in the U.K., Q. 244). Again, using arguments reminiscent of the energy conscious advocates of the present day, he suggested that warmth would be available more economically by heating the passages rather than the rooms. Moreover, he considered that a stove placed in the entrance hall, or at the foot of the stairs, would circulate the heat throughout the house, and thus minimise either the number or the capacity of the fires required in the rooms.

Speaking on the matter from his own experience, he observed:

"I had occasion some years ago to make inquiry as to the difference in the quantity of fuel required to heat large buildings, such as churches and schools, by means of Gill stoves and open fires, and the result that I came to was that about five times the quantity of coal was burnt in an open fire that was required in a Gill stove. So that there is obviously very great scope for economy in the use of coal for household purposes".

(Report, Coal in the U.K., Q. 244).

Again, in arguments similar to those of our own times, he suggested that the scarcity of coal and its consequent price increase would ensure that the public would demand more economical heating devices and avail themselves of those already existing.

Throughout his life, Armstrong was seldom bound by existing developments, but was always concerned with to-morrow's technology. As he stated in his Presidential Address to the British Association, "The more we extend our view, the more conscious we shall be of the immensity which lies beyond". This attitude was equally apparent in his evidence before the Royal Commission and in his plea for greater economies in fuel consumption. Having discussed the wastefulness of domestic coal fires, he could almost be said to have envisaged to-day's central heating systems when he suggested that:

"I think the best mode of heating is by hot water. The objection to it is that it involves a much more expensive apparatus, but the economies I have mentioned can be accomplished without any increase in the cost". (Report, Coal in the U.K., Q. 245).

Although he proposed no definite plan, he strongly urged that even with the existing technology, the principles of central heating should be applied, for he argued:

"If you generate the heat at the lowest point of the house, it will diffuse itself over the whole house, and the passages will convey it everywhere. Moreover, the air, being warm would come in at the doors without producing any disagreeable draught". (Report, Coal in the U.K., Q. 249).

At this point, Armstrong was asked to state his experience at the Elswick Works regarding the economy of fuel in the production of iron.

Noting that the blast furnaces in question were of recent construction, the Chairman presumed that Armstrong would have used the latest techniques. In the event, the only improvements to which Armstrong would admit were those of making the furnaces unusually high and utilising the gases to effect greater economies. When asked to elaborate further, Armstrong indicated that his partner, Captain Noble, who had carried out recent investigations on the subject was ready to supply the information. (Report, Coal in the U.K., Q. 250).

Nonetheless, he did mention, briefly, the economical workings of the blast furnaces at Elswick, where they used coke rather than coal and where, when both furnaces were in blast, they burned off the gases for further utilisation. When pressed further, he indicated that coal was never used for producing steam or hot air. "We apply the gases to both purposes", he replied, "but we scarcely find them sufficient". (Report, Coal in the U.K., Qs. 255-257).

His evidence then revealed his concern for greater fuel efficiency in steam engines for he observed that: "With regard to the consumption of fuel for motive power, the waste is, in a theoretic point of view prodigious, and in a practical point of view very large". (Report, Coal in the U.K., Q. 260). He then argued that even the best steam engine was utilised only to one tenth of its capacity, and the most common high pressure steam engines were used to only one thirtieth of their potential. Thus, he maintained, there was ample scope for improvement. Nonetheless, he wondered how far it would be possible to carry out the desired improvements, even though, "by substituting engines of good construction for engines of bad construction you might easily save 50% of the present consumption". (Report, Coal in the U.K., Q. 260).

When the Chairman indicated that he had received a letter from Sir

Daniel Gooch indicating that a steam engine consumed fuel at the rate of 8 pounds per horse power per hour, Armstrong replied that in the "several thousands of circulars" which he had, personally, received on the subject, that seemed to be a fair estimate, although the boilers of simple construction in normal use in manufactories generally used about 10 pounds an hour. "But they are the most wasteful of all", he admitted. (Report, Coal in the U.K., Q. 261-261).

When questioned further, Armstrong admitted that these engines could be fired with average quality coal, which in the North of England meant cheap steam coal. On the other hand, he suggested that further savings could be achieved only by substituting more expensive steam engines which were not so easily managed. "They would be liable to frequent interruptions and repairs", he averred, "and would require more deliberate attention". (Report, Coal in the U.K., Q. 265). After discussing several types of engine, during which Armstrong indicated that a single tube Cornish boiler was the type generally used at Elswick, he was asked if there were any other areas of motive power or metallurgy where greater economies could be effected. Although he admitted that it would take time, he did suggest that eventually, "the principle of the caloric air engine with the regenerator will to a great extent supersede the steam engine". Indeed, he argued that "for all manufacturing purposes, as well as for the production of power, I think that the regenerative principle is the one that possesses the greatest promise".

He supported this view by observing that the regenerative process captured the heat which would otherwise be lost, and used it again. Noting that it was customary at that time to feed the furnaces with cold air and to discharge very hot air, he argued that by re-cycling the hot air so that it heated the cold air as it entered the furnace, "there would be manifest gain". This, he reminded the panel, was the principle on which William Siemens had built the furnace for his experiments. Enlarging on the principle of the application of arrested heat, Armstrong claimed that, when applied to an air engine it ought, in theory, to give "incomparably more effective power than a steam engine" because, in the latter, only a very small amount of the heat imparted to the boiler was actually used. Indeed, working on the premise that "heat and motive power are interchangeable terms", he argued that the quantity of power obtained is in direct proportion to the amount of heat which disappears. In the case of the steam engine, he observed, it was the one tenth he had earlier calculated.

By contrast, by using the air engine, coupled with the regenerator, the main source of wastage in the steam engine would be avoided, because any heat passing from the air engine would be arrested by the regenerator, recirculated and used again, instead of being dissipated as before.

He further noted that in all manufacturing processes where heat is applied, there is always some material, like iron ore, to be heated. In this case, the products of combustion pass off at a higher temperature than that of the substance being heated. Thus, if this heat is not recovered, the wastage is enormous. (Report, Coal in the U.K., Q. 272). He then observed that the heat is more economically applied at the beginning of the process than at the end, and he substantiated this argument by reference to Siemens' method, wherein the heat, which would otherwise have been wasted, was absorbed by massive brickwork below the furnace. Thus, the gaseous fuel and the air used in combustion were already warmed before they entered the furnace, giving an additional measure of heat to that which was normally available.

Although, as Armstrong observed, this method should, in theory, have been perfect, in practice it was only partially successful. Nevertheless, he acknowledged that this was the method used extensively at Elswick, which despite certain drawbacks, they were ready to develop. Even so, he was not prepared to accept "the full advantage claimed by Mr Siemens", chiefly because the production of gas continued whether or not the furnace was in use, although he did concede that this, "like other practical defects will probably be surmounted in time". (Report, Coal in the U.K., Q. 273).

When Captain Noble, in turn, was asked to give evidence, the Chairman suggested that he had had 'considerable experience' in the operation of blast furnaces, to which Noble replied that he was 'pretty well acquainted with the manufacture of iron'. (Report, Coal in the U.K., Q. 481). Indeed, during his subsequent examination, he revealed that he had conducted extensive experiments at Elswick on the subject, and that his conclusions 'agreed pretty well' with those of the local ironmaster, Isaac Lowthian Bell. (Report, Coal in the U.K., Q. 483). These experiments convinced Noble that as much as two thirds of the heat produced by the coal in the furnace went off in waste gases, but if these were subsequently burned, the heat could be utilised for warming up water, and other purposes. When asked by Armstrong if there would be any margin for economy by applying greater heat to the furnace in the first place, Noble replied, 'Yes, undoubtedly'. (Report, Coal in the U.K., Q. 502). Throughout his evidence, it was apparent that Noble's findings not only agreed with those of Lowthian Bell, who was also a witness, but with William Siemens who, as one of the panel, further concurred when he suggested three clear savings: 'one on account of the greater absolute heat in the furnace, the second from more perfect combustion and the third from more complete regeneration'. (Report, Coal in the U.K., Q.556).

Siemens' assessment of Noble's findings is vital, as he was an acknowledged expert on the subject. When, in 1844, the British Association had encouraged Playfair and Bunsen to investigate the efficiency of the blast furnace in the smelting of iron, they proved that above 80% of the heat was wasted. Siemens and Bessemer duly responded to this implied challenge, and by the 1860s they had made iron and steel available on a hitherto unknown scale. (Checkland, pp. 89 and 92). It will be recalled that it was this lack of suitable materials at an early stage that, literally, caused Armstrong sleepless nights during his original experiments with his Number One Gun. Now, the wheel had come full circle, and it was a measure of the effectiveness of Armstrong's operations at Elswick and the ability of his young managers that men of Siemens' scientific reputation agreed with their findings.

In passing, it is appropriate to compare Armstrong's own career with a modern description of that of Bessemer and Siemens:

'Their careers were in significant contrast to those of the mechanical engineers who had held the palm until the mid century. Bessemer and Siemens were experimentalists first, who became industrialists in order to demonstrate the commercial soundness of their processes'. (Checkland, pp. 92 - 93).

Meanwhile, further evidence of Armstrong's increasing national prestige is seen his appointment, on 16th March 1870, as Chairman of the 'A' Committee of the Royal Commission with the remit to study possible depths of working the coal seams. By 16th June 1871, the work was so far advanced that the members met and issued their first draft report. (Report, Coal in the U.K., Vol. I, p. vi). Other notable appointments, which had followed in rapid succession, included the Presidency of the Institution of Mechanical Engineers in 1861, 1862 and 1869; membership of the Iron and Steel Institute from its inception in 1869; President of the North of England Mining and Mechanical Engineers in successive years 1872 - 75, and President of the mechanical science section of the British Association at York in 1881. While holding the last two offices, he used the occasion to return once more to the subject of the coal supply. (D.N.B. sub Armstrong, p. 67).

It now becomes increasingly apparent that, by the mid 1860s, Armstrong is far removed from a provincial figure, recognised solely as head of a Tyneside factory, concerned with the manufacture of hydraulics and armaments. Evidence of his higher profile is seen in his membership of one of the London's most prestigious clubs - the Athenaeum - from which he conducted some of the business of the Royal Commission. National appointments were not only proof of his new status, but they left him with less and less time for the day to day running of Elswick and for the paternalistic social entertaining of his employees in his own home, which had characterised the earlier years. Increasingly, that part of the business was left to his able young management team while he adopted the rôle of the archetypal national president; the scientific consultant; the guest speaker; the country squire, and the other social appurtenances which his knighthood bestowed upon him, and for which, through his family connections, his legal training and engineering inventiveness, he was, in fairness, richly endowed.

CHAPTER VIII.

SOME WIDER ASPECTS OF ARMSTRONG'S LIFE AND WORK.

Armstrong's contribution to hydraulics and engineering brought him almost universal recognition which, from the 1860s to the end of his life in 1900, was expressed in academic as well as national and international honours. In 1862 Cambridge University awarded him an honorary LL.D. degree; in 1870 Oxford made him a D.C.L., and Durham gave him a similar honour four years later. In 1892, when he was 82 years old, Dublin made him a Master of Engineering.

As early as 1850, he had shared the prize given by the Glamorganshire Canal Company, for the success of his hydraulic crane and accumulator, 'for the best machine to transfer coal from barges to ships', and in the same year he received the Telford Medal in silver from the Institution of Civil Engineers. This was for his paper 'On the Application of Water under considerable pressure for working Engines, Cranes and other Machinery'. (Minutes of Proceedings of the Institution of Civil Engineers, Vol. X, 1850 - 51, p. 65). In observing that several papers submitted by the Telford Medal winners were not only intrinsically valuable, but had an immediate application, the Report continued: 'The possibility of obtaining a motive power more economical, in its application than those ordinarily in use, especially in cases where the period of action were intermittent, was well treated by Mr. Armstrong in his paper, and the elaborate drawings of different kinds of machines already in action (used for illustrating the paper) clearly demonstrated the capability of the general application of the system'. (Proceedings of I. C. E., Vol. X, 1850 - 51, p. 67).

Some years later, in May 1878, the Society of Arts awarded him the Albert Medal 'because of his distinction as an engineer and as a scientific man, and because of the development of the transmission of power - hydraulically - due to his constant efforts extending over many years, the manufactures of this country have been greatly aided, and mechanical powers beneficially substituted for most laborious and injurious labour'. (Journal of the Society of Arts, 28th June, 1878, p. 751). Armstrong received the medal the following year from Edward, Prince of Wales, in his capacity as President of the Society of Arts, at a ceremony in Marlborough House. (Journal of the Society of Arts, 9th May, 1879, p. 497).

In 1891 the, by then, Lord Armstrong, received the Bessemer Medal from the Iron and Steel Institute, of which he was a founder member, 'for his eminent services in connection with the industries of iron and steel'. At the presentation, the President, Sir Frederick Abel recalled that Armstrong's other scientific experiments included those 'on the elasticity and the first moving point of iron and steel concerning which Lord Armstrong had published some interesting results'. Even more important was 'his work in connection with the tempering of steel that had led to the introduction of the process known as oil-hardening which was in general use in connection with the construction of steel ordnance'. In asking Armstrong to accept the medal, Abel recalled that the recipient's 'many sided scientific tastes and high attainments were perhaps only thoroughly known to those who had the pleasure of his intimate acquaintance; but ---- had the energies of Lord Armstrong not been diverted into the particular channels which had led to the high position occupied by him as an engineer, the world would certainly have counted him among the most eminent electricians of the day'. (Journal of the Iron and Steel Institute, 1891, pp. 57 - 58).

Armstrong himself endorsed these views. Despite his commitment to hydraulics and armaments, through which he made his name, Armstrong, in later life, became so absorbed with his electrical researches that he maintained that if he had devoted to electricity the same time that he had done to hydraulics, the results would have been even more profitable. (D.N.B. sub Armstrong, p. 69). Indeed, he told Dolman, during a visit to Cragside in 1893, that he was then experimenting with the conversion of a low tension current to one of high tension. When Dolman suggested that electricity gave scope for almost inexhaustible study, Armstrong replied: "Yes, we are little more than at the beginning of the science. No one can say what the future of electricity may have in store for us". (Dolman, 1893, p. 577).

Foreign Orders and decorations followed in rapid succession, including a Knight Commander of the Danish Order of Dannebrog, the oldest order of chivalry in Europe. He received the Order of Francis Joseph of Austria, of Charles III of Spain, and the Rose of Brazil. He became Grand Officer of Saints Maurice and Lazarus of Italy and of the Order of the Rising Sun of Japan. (Watson Armstrong, p. 492). So many and varied were the honours that one admirer wondered whether he 'could get all his medals, from the Order of the Bath downwards on his coat'. (Quoted in B. Shurlock, Industrial Pioneers of Tyneside, 1972, p. 23).

Armstrong's life, from 1860 onwards, far from being a time of increased leisure, became what could be called 'the years of the President', since presidencies of many learned societies followed in rapid succession. Each of his Presidential addresses not only outlined the country's technical development to date, but pointed the way forward with such remarkable vision as to be relevant even today.

In his Presidential address to the Institution of Mechanical Engineers in 1861, he began by tracing the development of Watt's steam engine and its application to industry. Noting that, from the days of Watt, propulsion of carriages by steam power had made but limited progress, he paid tribute to the mechanical genius of his fellow Northumbrian:

"From the days of Watt, who first suggested the application of the steam engine for this purpose, up to the time when George Stephenson, the illustrious first President of this Institution, devoted with wonderful perseverance the inventive powers of his mind to its perfection, the Locomotive Engine had attained no practical value. But in the hands of Stephenson it took as great a stride as did the condensing engine in the hands of Watt. The ever memorable 'Rocket', which carried off the prize at the opening of the Liverpool and Manchester Railway, became the type of all succeeding locomotives, just as the condensing engine as left by the original master has remained the standard of that class of engines. Of all the achievements of mechanical engineers the locomotive engine is the greatest. As a work of skill, it presents the most remarkable instance of strength and power, combined with lightness, that can be found in the whole field of mechanical engineering; while in point of utility, it has served more than any other invention to develop the resources of every country in which it has been employed". (Proceedings of the Institution of Mechanical Engineers, 1861, pp. 111-112).

Not only did Armstrong acknowledge the intrinsic mechanical value of the steam engine, but its inestimable potential as an agent of civilisation, communication and social advancement.

"By promoting centralisation, steam communication has made good government cheaper and more practicable. It has strengthened the hands of the executive, broken down provincialism, opened out new markets for produce, established new fields of supply, equalised prices, and facilitated colonisation. It has given fresh life to old nations, and added to the vigour of new ones. A Greek poet with seemingly prophetic import has described the business of the road-making sons of Vulcan to be that of converting the uncivilised places of the earth into civilised. True sons of Vulcan, the god of iron and of fire, are those men who in our time have been the pioneers of civilisation, by giving steam-worked railroads to the world, and applying the steam engine to the highways of the ocean". (<u>Proceedings of I. Mech. E.</u>, 1861, p. 112).

But these were not merely the customary courteous tributes to a former President. Armstrong realised that the success of Elswick lay as much with the production of steam locomotives and steam ships as it had done originally with hydraulic cranes.

He went on to observe that the development of these inventions could only take place in the context of a parallel development in tools and constructive machinery. Equally, he paid tribute to the work of Whitworth - a previous President and Armstrong's future partner - whose name, he averred, "will ever go down to posterity as that of a man who has been instrumental in raising to its present height this important branch of mechanical engineering". Nonetheless, he acknowledged that despite the increasing perfection of tools and technology, in the final analysis production depended on the human factor and its commensurate development. "If the skill of the artificer had not kept pace with the progress of invention", he maintained, "the mechanical production of the present day would not have been possible".

He further argued that our native mechanical skills could develop only in the presence of our abundant supply of the requisite raw materials of coal and iron, and suggested that: "It is the iron and not the golden age which is the true age of civilisation; and England has led the way in the march of progress, chiefly through her skill and energy in producing this metal and applying it to mechanical purposes". (<u>Proceedings of I. Mech. E.</u>, 1861, p. 113).

As always his argument turned on a subject with modern relevance. Having outlined the development of the mechanical arts in a peaceful context, he turned to speak of their application to military purposes. Although he condemned war for its inherent suffering and misery, he did acknowledge that it was not devoid of all good, especially when it afforded opportunities for the manifestation of some of humanity's noblest attributes like courage and patriotism, self devotion and honour. Moreover, he noted that, from the time of ancient Rome, military conquests have heralded the imposition of a particular civilisation on the conquered peoples which was often to their advantage. Indeed, he argued, the universal acknowledgement of military distinction gave the lie to the moralists who considered war and crime as equally detestable.

"Whatever opinions may be held on this subject", he argued, "it is useless to take utopian views of the duties of nations and the principles which might settle their intercourse". (Proceedings of I. Mech. E., 1861, p. 114). Again, in reasoning appropriate to the modern arms race, he continued: "So long, therefore, as any one nation maintains its armaments, it is an absolute necessity that others should do the same, unless they choose, by their inability to resist, to tempt a rupture, and are content to succumb in the event of its occurrence". (Proceedings of I. Mech. E., 1861, p. 114).

Conceding that the French were always well advanced in military matters, it was as much in his capacity as the head of Elswick as that of President of a learned society that he observed that: "They have of late years devoted their energies to two most important subjects - the rifling of ordnance and the defensive armour of ships". (Proceedings of I. Mech. E., 1861, p. 114). Although these were two aspects for which Elswick was to become world famous, it was in the general context that Armstrong noted that "their advances have necessitated similar steps on our part and we have certainly no reason to suppose that we are behind in the race".

Since, at that time, he still occupied his Government post at

Woolwich, it is not surprising that he further noted that he had been "personally much concerned with the first of these subjects", and had had "opportunities of observing the merits and defects of the various descriptions of armour plates with which experiments have been made by the direction of government".

He then spoke of the limitations of cast iron in the construction of heavy ordnance, and observed that guns made of that material were unable to resist the severe strain imposed by the latest elongated rifled projectiles. This limitation became increasingly apparent with the growing demand for more powerful artillery, and the increasing fire power of the newest guns seemed to preclude entirely the use of cast iron in their construction.

In America, he noted, improvements had been made in the manufacture of cast iron ordnance by applying water to cool the castings from the inside and thus enable functional guns of this metal to be made with a much larger bore than has been possible with English methods. Unfortunately, this method had been tried only in conditions where the guns were not rifled and where hollow projectiles were being used. Nevertheless, he argued, such limited success did not detract from the more generally held assumption that cast iron was not suitable for constructing rifled guns designed to project solid shot, especially in the case of large bore ordnance. In view of Armstrong's undoubted mastery of this subject, his words would have a particular significance. Evidence of his own detailed and protracted research and his experiments at Shoeburyness and in Northumberland is apparent in his observations that "even when strengthened by wrought iron hoops, the tendency of cast iron in a gun is to become weaker by every succeeding discharge. This is owing to minute fractures occurring in the bore, generally near the vent and gradually extending until they terminate in the rupture of the gun. If therefore cast iron guns are to be made available at all as rifled ordnance, it can only be by confining their use to hollow projectiles and light charges". (Proceedings of I. Mech. E., 1861, p. 115).

By using wrought iron, he argued, "equal efficiency would be obtained by using half the weight of metal, and on this grand scale alone, the superiority of the latter is decisive". Nonetheless, because wrought iron was subject to flaws during the forging process, where it was used in conjunction with an interior explosive charge, as in a gun, such flaws were fatal. Wrought iron, he maintained, was even more disastrous than cast iron when used as a solid block in the construction of guns. Whereas a successfully made wrought iron gun may possess greater initial powers of resistance, because it had a greater propensity to concealed flaws than cast iron, its overall performance was more uncertain and dangerous. Steel, by contrast, had different characteristics. When it was solidifying from its liquid state, while in its crystalline form, it was always hard and brittle. Only during its subsequent hammering process did it acquire its characteristic ductility and toughness. "This alternative process of hammering is perfectly effectual", he claimed, "when the thickness of steel is small; but when it is wanted to be forged in a large mass, it appears to be a matter of the utmost difficulty to effect the required change". Then he gave due credit to the achievements of the firm which, until the First World War, was to be Elswick's only world rival in armaments. "It is seldom that the enterprise of English manufactures is exceeded by that of foreigners", he claimed, "but in the production of steel forgings of large dimensions, Krupp of Essen has taken the lead of all steel makers in this country. He has met the difficulty of toughening large masses of cast steel by using hammers of extraordinary weight, and I believe that equal success will never be attained in England without adopting similar measures". (Proceedings of I. Mech. E. , 1861, p. 116).

Armstrong, apparently, took due cognisance of Krupp's success because one of his biographers made the following observations on 1893:

'The hydraulic crane was the beginning of the great Elswick firm, but it is in the construction of ordnance that its greatest fame has been obtained. In this department, no fewer than 5,000 men are often employed, some in the immense foundry (90 yards long by 70 wide) and the hammer shed; others in the boring and finishing shops. The largest of their steam-hammers is of thirty five tons weight, and to see it pressing a mass of red-hot metal into the shape of a gun is one of the most interesting sights in Elswick Works. This splendid piece of mechanism, known to the workmen as "Big Ben", is considered to be the finest of its kind. It is so delicately adjusted that it will crack a nut without breaking the kernel, and this with the same power which pulverises tons of metal with a thud that shakes the floor. When the Prince of Wales visited Elswick, nearly ten years ago, he placed his hand under this gigantic tool, and it just touched the flesh, which, with equal facility, it could have crushed'. (Dolman, 1893, p. 582).

It is perhaps appropriate to note, at this juncture, the vast scale on which the Elswick firm was then operating, in the field of armaments alone, as Dolman continues:

'In the ordnance department, there are guns in all stages of construction, and the larger ones are finished in the same place as they were begun. The smaller ones are finished - polished, browned and varnished - in a separate shop. Most of those one sees being made have been ordered by the British and foreign governments, but at "Armstrong's" there is always kept a stock of ordnance of different kinds and sizes. It is from the specimens kept in these galleries that the representatives of the war offices of the world give their orders. They are sold ready-made when guns are required at short notice in any quarter of the globe. Just before my visit the stock of probably a hundred pieces had been slightly reduced in compliance with urgent orders from Siam, which was then on the threshold of war with France. Before the final departure of the guns, however, they have to be taken considerable distances to be tested, some going to Ridsdale, some to Rothbury, and others, of the biggest kind, to a place on the Western coast. To indicate the complexity of the work of making modern ordnance it is only necessary to mention, perhaps, that in this department of "Armstrong's" there are no fewer than eight hundred to nine hundred machines'. (Dolman, 1893, p. 582).

In his customary manner, Armstrong continued his Presidential address with a vision of future technological developments by observing that "it will be a great era" when a metal is produced having the combined advantages of the toughness and ductility of wrought iron with the homogenous character of cast metal. Even given the scientific feasibility of such advancement, he wondered whether it would be economically viable for large scale usage, but he noted that among others who submitted papers at that meeting was Bessemer, "whose exertions in this field of enquiry have attracted much attention". (Proceedings of I. Mech. E., 1861, pp. 116-117).

His lecture then turned to the application of iron in the construction of artillery which, given his Government post, and his research at that time, enabled him to speak with some authority. He described in some detail "the system of manufacture which I myself adopted, which may be designated the 'coil' system", and explained how, as successive layers of coil were applied, each one was shrunk upon the one beneath it. This particular method of construction overcame the problems of imperfect welding which were so apparent in normal manufacture. The lines of welding, he claimed, would not run lengthwise down the cylinder, and risk causing a burst at the point of explosion through an imperfect weld. Instead, the welds would now be nearly transverse to the cylinder, "in which direction they would have little tendency to weaken it when exposed to a bursting force, even should they not be perfectly sound". Moreover, he claimed, the coil system afforded every opportunity of discovering and rejecting any unsound material at an early stage in manufacture. Furthermore, he asserted that guns constructed by this method could be made to any size, without the problems formerly encountered when forging large blocks of steel or iron.

The problems posed by artillery against armour plated ships next claimed Armstrong's attention. In view of Elswick's later involvement with ship-building generally, and war ships in particular, it is appropriate to note, even at this early stage, Armstrong's own views on the subject. They suggest that, when the merger eventually took place facilitating the firm's diversification, it was not merely an economic convenience, but part of Armstrong's personal interest and his own considered strategy.

The main thrust of his argument showed that however thick the armour plating became, correspondingly heavier guns would be employed to pierce it. Nonetheless, he maintained that even under those conditions, iron plated rather than timber ships were a stronger bastion against artillery shells. "The former", he argued, "will effectively resist every species of explosive or incendiary projectile, as well as solid shot from all but the heaviest guns which can never be used in large numbers against them". Indeed, he concluded, so far as line-of battle ships were concerned, the choice lay between armour plated ships or none at all.

Having thus argued his case, he next turned his attention to the most appropriate impact resisting material - a subject which, at that time, was arousing considerable interest in Sheffield and the iron manufacturing districts at large. Again, in a reference to his own experience, Armstrong maintained that either the hardness or the lamination of metals used in armour plating could cause the shell to fracture the material rather than to pierce it. The hole, he explained, had a broken circumference, rather than the smooth one of a punch. Thus, he claimed, "the softer the iron, the less injury it will sustain, and I apprehend that steel in every form will, from its great hardness, be found less effective than wrought iron, while the cost would be very much greater". (<u>Proceedings of I. Mech. E.</u>, 1861, p. 118).

On the subject of lamination, he argued that experiments had proved that any given thickness of iron composed of successive layers of thin plates was considerably weaker as armour plating than the corresponding thickness in solid form. He furthered his argument by stressing that laminated metals were merely an aggregation of separate plates, with all their inherent weaknesses. Again, he threw down a challenge to scientists and engineers when he suggested that if the inherent weaknesses of lamination could be obviated, "rolled plates would, in my opinion, be preferable to forged, since the iron would acquire a more fibrous condition, but the existence of this liability appears to turn the scale in favour of forging".

Despite his own researches into weapons of war, Armstrong was, essentially, a man of peace. "I hope the time is far distant when the great questions concerning attack and defence may receive a practical elucidation in actual warfare", he declared, "but I trust that in the course of our efforts to solve them, discoveries may be made which will be as useful for the purposes of peace as for those of war". (<u>Proceedings of I. Mech. E.</u>, 1861, p. 118).

In concluding his address, Armstrong made some general references to the prosperity brought to the nation by mechanical engineers, but regretted that their endeavours were restricted by the patent laws. "That dauntless spirit", he declared, "which in matters of commerce has led this country to cast off the trammels of protection, has resulted in augmented prosperity to the nation showing the injurious tendencies of class legislation when opposed to general freedom of action". (<u>Proceedings of I. Mech. E.</u>, 1861, p. 118).

The patent laws, he maintained, showed a less enlightened policy than the other laws of protection, and worked not only to the detriment of the inventor, but against the general prosperity of the country at large. Philosophers "who furnish the light of science to guide to useful discovery", were both unrecognised and unrewarded, he averred. At practical level, men like Watt and George Stephenson, whose ingenuity was of inestimable benefit to mankind, not only spent most of their lives perfecting their inventions with little monetary reward, but often became embroiled in expensive and extensive litigation over the priority of their ideas. By contrast, he argued, there were numerous cases of people acquiring untold wealth simply by seizing on a new concept at the very surface of human endeavour, and monopolising the idea. On the subject of monopoly, he further argued that many inventors were forced into becoming patentees for no other reason than that they wished to continue to practise their own ideas.

Although he, personally, believed that the prestige of successful invention brought its own reward, he hesitated to suggest that this was an adequate reason for the abolition of protection. Nonetheless, he urged the urgent reform of this branch of legislation, arguing that practical science was being obstructed by the very laws which should have encouraged its progress.

Given such developments, he ended his address with the hope that the "genius, enterprise and intelligence", which had characterised the mechanical engineers of the past would inspire their future endeavours. (Proceedings of I. Mech. E. , 1861, p. 120).

In 1877, he returned to the problems of breech loading guns, which he completed at the beginning of 1880. His results were so satisfactory that even the reactionary minds of the military and politicians who had impeded his earlier progress had to acknowledge their folly in continuing to manufacture the unwieldy muzzle loaders with their built in obsolescence. By the end of 1880, Armstrong's motto, 'Perseverance generally prevails' overcame their resistance and persuaded them to adopt, once more, the breech loading guns with their polygroove rifling. (D.N.B. sub Armstrong, p. 67).

Nevertheless, his strenuous application to hydraulics and ordnance exhausted neither his energy nor his interests. As presidencies of professional organisations followed in rapid succession, he used the opportunities to expound his theories on the economic use of fuel and alternative sources of energy. Apart from his Presidential address to the British Association in Newcastle in 1863, and his valuable evidence before the Royal Commission to inquire into the duration of the British coalfields in 1866, he twice returned to the subject. First in his Presidential address to the North of England Institute of Mining and Mechanical Engineers in 1873, and again at York, in 1881, when he was President of the Mechanical section of the British Association. Here he challenged the efficiency of the steam engine with its 'monstrous waste' against the electrical means of obtaining power. At Newcastle in 1863, he had concluded that 'whether we use heat or electricity as the motive power we must equally depend upon chemical affinity as the source of supply. ------- But where are we to obtain materials so economical for this purpose as the coal we derive from the earth and the oxygen we obtain from the air?' (Report of British Association, 1863). Two decades later, electrical science had advanced so rapidly that he was prepared to consider the feasibility of using a thermo-electric engine, 'not only as an auxiliary, but in complete substitution for the steam engine'. (Report of Mechanical Section of British Association, York, 1881, p. 772). Furthermore, in conditions where man could utilise 'the direct heating action of the sun's rays', he maintained that 'the solar heat operating upon an area of one acre in the tropics would, if fully utilised, exert the amazing power of 4,000 horses acting for nearly nine hours every day'. (Report of B.A., 1881, p. 772). He also prophesied that, 'whenever the time comes for utilising the power of great waterfalls, the transmission of power by electricity will become a system of vast importance'. His prediction was to be fulfilled in a remarkable way in subsequent imaginative uses of natural resources at places like Geneva, Niagara and the like. (D.N.B. sub Armstrong, p. 68).

Armstrong's study of hydraulics continued throughout his life. Having received the Telford Medal from the Institution of Civil Engineers in 1850, he presented a paper to them in May, 1877, when he was their Vice President. This useful treatise, some of whose details have already been noted earlier in this study, traced both the history of hydraulics and Armstrong's involvement in their development.

His own commitment to the subject, he recalled, stemmed from the days when he "was then engaged in a profession entirely unconnected with engineering", and when some of his earlier designs had suffered because of his "inexperience, at that period, of mechanical construction". Next, he outlined the development of some of his own ideas from the overshot water wheel in Craven in Yorkshire, and the application of his theories to the cranes on Newcastle Quayside, to the water supply of Newcastle and Gateshead, and the hydraulically operated machinery at Liverpool Docks. Recalling that, when he had been unable to utilise the water supplies from town reservoirs, he had developed his accumulator to overcome the difficulty. (Minutes of Proceedings of Institution of Civil Engineers, Vol. L, 1876 - 77, pp. 64-69 passim).

Hydraulic cranes, he observed, were first adopted in 1848 for railway station purposes by the York, Newcastle and Berwick (subsequently the North Eastern) Railway Company. The Trafalgar Street goods station at Newcastle was the venue, and the credit for such foresight, he maintained: "belongs to Mr Harrison, Past-President of the Institution, who has, throughout, been very instrumental in the promotion of this system". (Proceedings of I. C. E., Vol. L, 1876 - 77, p. 69). It is not inappropriate to note that Mr T.E. Harrison was appointed as independent assessor in the deal between the Government Ordnance Factory at Woolwich, and Armstrong's Elswick Works during their joint venture, 'to settle and agree on the amount to be paid as a fair and equivalent compensation on money to us ---- under the terms of the said indenture'. (House of Commons Parliamentary Papers, 1863, Vol. XI, Appendix to Report from the Select Committee on Ordnance, p. 491). Furthermore, successive generations of his family continued their professional association with the North Eastern Railway throughout its history as the London and North Eastern Railway, and, eventually, as British Rail. His son and grandson were also railway engineers. The former, Mr C.A. Harrison, was Chief Civil Engineer to the North Eastern Railway Company at the turn of the century. He designed the King Edward Bridge across the Tyne, opened in 1906 by King Edward VII. (The Newcastle Weekly Chronicle, 14th July, 1906, p.9). This bridge afforded a speedier access to Newcastle's Central Station, for main line trains between London and Edinburgh, than did Robert Stephenson's High Level Bridge which was opened by Queen Victoria in 1849. Nonetheless, the two bridges are still fully operational in the days of the High Speed Train, and are to be adapted under British Rail's East Coast Main Line Electrification Scheme, currently under construction.

In tracing the development of his own research, Armstrong recalled that he "had been led on from the primary idea of utilising mountain rills to the ultimate one of accumulating and distributing the power of a steam engine through the medium of water pressure". (Proceedings of I. C. E., Vol. L, 1876 - 77, p. 72). Nevertheless, he acknowledged that he had not been able to test his ideas to the full until 1849, when he met Thomas Sopwith, who, as noted earlier in this study, was mining agent in the Wentworth Blackett Beaumont mines in Allendale. The overshot water wheel then employed in these particular mines failed to give an adequate water supply, so Armstrong and Sopwith, after considerable experimentation, replaced them with water-power engines. (Proceedings of I. C. E., Vol. L, 1876 - 77, pp. 72-73).

Armstrong then recalled the deep interest evinced by J.M. Rendel in the application of hydraulic machinery, which was realised in the installations at the docks of Grimsby and Birkenhead. Equally, in 1851, Brunel advocated the use of hydraulic machinery for railway operations, generally, and erected a large plant for this purpose at Paddington station. The example set by the Great Western Railway Company was soon emulated throughout the railway system of Britain. From this time, too, Armstrong noted that because chief engineers adopted the idea of transmitting the power of a steam engine through an accumulator, it was soon accepted for general use. He then acknowledged the wealth of research done by engineers to advance the system by applying it to their own specific needs.

Nonetheless, he feared that the full potential of "the original idea of utilising mountain torrents, which was the progenitor of the accumulator system", had only partially been realised, even although the numerous water falls in the remote areas of the country were overlooked as possible sources of power, due to the abundance of cheap coal. Even so, he prophesied that such water falls could, in the future, "become a most important source of motive power, applicable to every purpose, except that of locomotion". (Proceedings of I. C. E., Vol. L, 1876 - 77, p. 74).

Apart from outlining the various forms of machinery which could advantageously be operated hydraulically in mines, on railways and at docks, Armstrong then described the application of such principles to the movement of swing bridges and drawbridges. Of those mentioned in his speech, perhaps the most significant in the context of this study is that of the Swing Bridge across the Tyne at Newcastle, built on the site of the Roman bridge with its wooden superstructure supported on solid stone piers. Thereafter, a stone arch medieval bridge occupied the site, until the notorious flood of 1771 demolished all the bridges across the Tyne, except the one at Corbridge. A temporary bridge was erected until a new stone arch bridge, jointly sponsored by the bishop of Durham and Newcastle Corporation, was opened in 1781. This, the third Tyne Bridge on the same low level site, became an impediment to upriver industrial development, both to Armstrong's firm at Elswick and to the coal trade, which dominated the river traffic. Coals 'above bridge' had first to be loaded into keels which were small enough to negotiate the arches of the bridge, then, having been brought 'below bridge', were transhipped into waiting colliers. (Pamphlet, The Tyne Swing Bridge, Tyne and Wear Industrial Monuments Trust, p. 1).

When Armstrong's Elswick Works expanded and began to export their goods to ever widening markets, it was in his own best interest to improve the bridging of the river at that point. Remarkably, he chose to retain the 'low level' site of the previous bridges, in preference to the 'high level' sites favoured by all post-industrial bridge builders, from Robert Stephenson to the present day. Nonetheless, he overcame the inherent problems of this decision by making the central portion of his Swing Bridge rotate in either direction, and to align its river channels with those of Robert Stephenson's High Level Bridge. Although the usefulness of the Swing Bridge has declined with the industrial base of Tyneside, it still ranks as the most important hydraulic swing bridge in the country, while its permanent location so near to the place of its origin makes it of particular interest.

Meanwhile, Armstrong, speaking within a year of the opening of the Swing Bridge, described it as having "the swinging portion of 280 feet and the weight upwards of 1,200 tons". Whereas with "the Ouse Bridge, the whole weight rests upon the circle of live rollers, in the Newcastle bridge a relieving press is applied in the centre". (Proceedings of I. C. E., Vol. L, 1876 - 77, p. 85).

Designed and manufactured at Armstrong's own works at Elswick, the Swing Bridge opened to traffic in June, 1876. Coincidentally, the first ship to pass the new bridge was the Italian vessel the 'Europa' on its way to Elswick to take on board the largest gun that had ever been constructed.

Cochrane later described the scene. 'At that date in 1876, the gun was the largest gun in the world, the Swing Bridge was the largest swing bridge, the sheer-legs the largest sheer-legs and the crane the largest crane. Such a coincidence of circumstances sounds almost American in its superlatives. It only remains to be added that gun, bridge, sheer-legs and crane were all built by the Armstrong firm. For Elswick, it was indeed the day of big things'. (A. Cochrane, 1901, p. 76).

Armstrong's extensive paper, which took two meetings to deliver, was well received. Among many who contributed to the ensuing discussion was Sir John Hawkshaw who recognised it as 'an admirable description of a great number of applications of the important system of transmitting power, to which Sir William had so long devoted himself'. He described Armstrong's application as 'most ingenious', and acknowledged that he 'knew of no method which for many purposes was so serviceable'. (Proceedings of I. C. E., Vol. L, 1876 - 77, p. 89).

In 1882, the Institution of Civil Engineers elected Armstrong as their President. In his opening address, he noted that his predecessors had selected topics concerning the application of engineering to peaceful pursuits, yet he chose, unequivocally, to speak on the application of engineering to the defence of the country. Although he admitted that "the general amelioration of the material condition of the world is the noblest object of our science", he argued that "we live in a world of contention, where no individual state can insure its independence and carry on its industrial occupations in safety, without protecting itself against the possible aggression of its neighbours". On this basis, he maintained, the science of engineering had to be applied as much to war as to peace. Moreover, he suggested, engineering could, in future, become increasingly occupied with preparations for war "until the issue will be chiefly dependent upon the superiority of mechanical resource displayed by one or other of the contending parties". (Proceedings of I. C. E., Vol. LXVIII, 1882, p. 36). In view of the two World Wars of this century, when the opposing guns of Armstrong and Krupp hurled death and destruction at each other with such devastating effect, his words had a tragically prophetic ring.

Although, he argued, few nations were less aggressive than our own, in view of our own commercial interests which necessitated "our ships swarming over every sea, and conveying merchandise of enormous value", it was vital to protect our supplies from enemy attack. While he refused to be drawn into either the moral question on war or the political question on free trade, he suggested, nonetheless, that "we have the stern fact before us that national defence is, in our case, peculiarly a necessity". Having thus outlined his case, he maintained that the study of our defence was the legitimate concern of the engineer, and thus a worthy subject for his address.

He outlined his case by arguing that because war indemnities had degenerated into "mere exactions proportioned to the wealth of the vanquished", England, being so prosperous, was a worthy target for an unscrupulous aggressor. Moreover, its island geography made the country particularly vulnerable and thus dependent on naval power for protection. Nonetheless, he argued, "we cannot hope that she will ever again be so dominant at sea as before the introduction of steam navigation". He qualified this remarkable statement by suggesting that in the days of the sailing ship, when naval superiority "depended upon seamanship and an unlimited supply of sailors", we had no equal. However, when steam ships replaced sail, this revolution made naval warfare the concern more of the engineer than the seaman. (Proceedings of I. C. E., Vol. LXVIII, 1882, p. 37).

The second phase of this revolution, he averred, was the introduction of rifled ordnance and percussion shells. Regrettably, these innovations rendered obsolete "the whole fleet of wooden ships with which all our victories had been won, and which were the pride of the nation". In consequence, there developed the continuing rivalry between guns and armour which, he doubted, would never be resolved. "The most recent stage of this revolution", he maintained, "is that marked by the introduction of torpedoes against which our ponderous ironclads are no more secure than ships of thinnest iron".

The constant switch from defence to attack, he claimed, placed great strain on the naval authorities in decisions concerning ships and armament. "To stand still was impossible, while to act upon uncertain data was sure to lead to mistakes", he argued. In consequence, because the types and patterns of ships were constantly changing, vessels costing vast sums of money were obsolete almost as soon as they were built. Invulnerability, he continued, was a worthy goal, and while it seemed attainable, great sacrifices were made for its accomplishment. Unfortunately, he claimed, it was now realised that "invulnerability is a chimera". His preroration continued with arguments with modern overtones. Not only was armour plating useless against torpedo attack, he averred, but in the natural course of events, every successful increase in armour plating inevitably led to a corresponding increase in the power of artillery. Even our earliest iron-clads, like the "Warrior" had armour plating so thin that it could now be pierced by field pieces. Modern armour, he maintained, would need to be at least two feet thick if it were to resist the most powerful guns then afloat.

Speaking in greater depth on a subject that he had briefly outlined in an earlier address, he next considered the economic and defensive advantages of one ironclad ship against three unarmoured ships of far greater speed, but each carrying armour equivalent to the one armoured vessel. He argued his case on the grounds that the three lighter ships, apart from their numerical superiority, would have many other advantages:

"Being smaller, they would be more difficult to hit. Being swifter, they could choose their positions and be free to attack or retreat at pleasure. Being more nimble in turning, they would be better adapted both for ramming and for evading the ram of their adversary. Finally, the conditions of superior speed and agility would favour their use of torpedoes and submarine projectiles, although it is a question whether it would not be better to confine that species of attack to separate vessels specially constructed for that one particular purpose". (<u>Proceedings of I.</u>

C. E., Vol. LXVIII, 1882, p. 40).

In such an event, he claimed, the iron-clad would be subject to the combined fire-power of three ships, each carrying similar armament to her own, yet, because of their speed, her opponents would be able to steam around her, directing their fire where it would do most damage, until, at the appropriate moment, they would converge upon her and destroy her by ramming. Given the superiority of speed and numbers of the smaller vessels, Armstrong then wondered if the iron-clads had any future role to play. "For almost every other kind of service", he argued, "a numerous fleet of smaller and swifter vessels, unencumbered with armour, would clearly be preferable". (Proceedings of I. C. E., Vol. LXVIII, 1882, p. 41). As a means of protecting our commerce; of guarding our coasts against invasion; of assisting our colonies as and when required and generally maintaining our sea-borne supremacy, we needed a "far more numerous navy than we possess, or can afford to possess, unless we vastly reduce our expenditure on individual ships, and to do this, we must dispense with armour", he averred. Thus, by arguing for more numerous, swifter vessels, Armstrong effectively stated the case for the fast, more manoevrable, light cruiser of modern times.

Among those who had already experimented with such designs, Armstrong highlighted the work of George Rendel, whose light unarmoured ships of 1,300 tons could achieve a speed of 16 knots. Such vessels carried coal for 4,000 miles and, according to Armstrong, "have actually steamed 3,500 miles without replenishing". They were each armed with four forty pounder guns on the broadside and with two ten inch new type guns which, with nearly all-round fire, were capable of piercing 18 inches of iron armour. (Proceedings of I. C. E., Vol. LXVIII, 1882, p. 42).

National defence, including the protection of harbours was another concern of the engineer, according to Armstrong. Little had been done to protect our commercial harbours from attack, he claimed, and with our limited naval capacity, he feared that hostile cruisers could inflict immense damage, in the event of war. While advancing various forms of harbour defences, including both static battery guns and mobile gun-boats, which could carry the heaviest artillery, he nonetheless argued that no such defence was complete without the use of submarine mines.

His wide-ranging speech, covering artillery, projectiles, ships and harbour defences then turned to the improved types of gunpowder made necessary by the recent developments in artillery. In particular, he referred to the "elaborate papers on the subject, contributed by Captain Noble and Professor Abel", at the British Association meeting in Edinburgh, in 1871.

In his summary, Armstrong emphasised that the developments in naval warfare, as well as the design of ships highlighted the importance of mechanical as well as nautical acquirements on the part of both officers and men. "Breech loading guns, carriages fitted with all modern appliances, shot and powder lifts, mechanical rammers and torpedo apparatus, all combined with steam or hydraulic machinery, or with both, constitute mechanisms requiring to be supervised by officers qualified as engineers and to be handled by men trained in the use of machinery". (Proceedings of I. C. E., Vol. LXVIII, 1882, p. 55).

Thereupon, Armstrong gave a warning that, because of the rapid progress of artillery in the previous decade, many of our ships were armed with obsolete guns which would be no match for the modern artillery already being adopted by other naval powers. "No expense", he claimed, "should be spared in judicious experiments, seeing that (it) is trifling in comparison with that of mistakes". Indeed, he concluded, "the Government should bring into full play the abundant engineering resources of this highly mechanical country for increasing the efficiency of our National Defences". (Proceedings of I. C. E., Vol. LXVIII, 1882, p. 56).

This identification with the problems of naval design and marine warfare might, at first, seem to be a strange departure for Armstrong. Nonetheless, although he and his firm had, hitherto, concentrated on field guns, the advent of the iron-clad warships, made him recognise the need for a new type of armament and he seized the opportunity for commercial development. Gradually, his firm had been increasing its naval work since 1867, when he had signed an agreement with the ship building firm of Charles Mitchell of Low Walker on Tyne, whereby that yard built the ships and Elswick manufactured and fitted the ordnance. (Dougan, pp. 109 - 110).

Armstrong's involvement in warship design, and Elswick's diversification into naval construction will be considered in greater detail in a later chapter. Nevertheless, his views are more readily understood in the context of his existing association with Mitchell and Company, and the amalgamation of the two firms which took place only a few months after this speech was made. So important was this move that a recent biographer has stated:

'From this time dates the period of "The Great Elswick Works". In addition to the less glamorous, but still substantial engineering work, the business had become a mighty armoury, rivalled only by the Krupp's firm in Germany. (Krupp's was largely subsidised by the German Government whereas Armstrong's business had always been independent and competitive). Elswick was the only factory in the world - nationally owned or private - that could build a man of war and arm it completely'. (P. McKenzie, p. 100).

At Armstrong's final appearance as President of the Institution of Civil Engineers, in 1882, it was resolved unanimously: 'That the cordial thanks of the Meeting be given to Sir W. G. Armstrong, President, for his persevering endeavours in the interests of the Institution, for his unremitting attention to the duties of his office and for the urbanity he has at all times displayed in the Chair'. (Proceedings of I. C. E., Vol. LXXI, 1883, p. 217). Earlier in the Session he and Lady Armstrong had entertained members of the Institution in the South Kensington Museum, 'by permission of the Lords of the Committee of Council on Education'. (Proceedings of I. C. E., Vol. LXX, 1882, p. 271).

Although Armstrong's commitment to his immediate occupation became legendary, nevertheless, he often managed to combine work and pleasure. For instance, in 1872, he was invited to visit Egypt to advise the Khedive on the means of preventing the cataracts of the Nile from interrupting the flow of river traffic. Previously the French, who had maintained considerable influence in Egypt, had built a very costly dam across the lower Nile, which had proved a total failure. Nonetheless, they were still reaping vast profits from the supply of machinery to several sugar refining factories in the area. In turn, the British engineers, who had secured the contract for enlarging the harbour at Alexandria, were equally unscrupulous in reaping their own extravagant rewards. Sir John Fowler, who had been appointed engineer to the Khedive Ismail, largely through the influence of Edward, Prince of Wales, after his tour of the area, was empowered to safeguard the interests of the Khedive and to advise him on further engineering undertakings. Although, in Stuart Rendel's opinion, Fowler was not an outstanding engineer, he was, apparently, 'a first rate engineering witness in Parliamentary Committees and generally a judicious and successful promoter of engineering projects'. (Hamer, pp. 36 - 37). Indeed, Rendel's views seem to mirror those of Armstrong on the importance of marketing as well as production, when he observes that 'more success and profit attend the placing of goods across the counter than the production of the goods themselves'. He further maintained that 'if you take an architect having art, you will have a man incapable of business, whereas if you take a good business architect, you will find him ignorant of art, so in engineering it is difficult to find in one man a scientific engineer and an engineer who knows how to get engineering projects started and carried out'. (Hamer, p. 37).

Because the Khedive was anxious to establish communication between Lower and Upper Egypt, including the Sudan, Fowler was soon involved in this project. Although the Nile formed a natural channel of communication, the presence of cataracts along the river appeared to pose an insurmountable obstacle. Fowler realised that Armstrong's expertise in hydraulics would be invaluable in this situation, and under the guise of combining business with pleasure, the latter was persuaded to go and study the problem. Accompanying the party at Armstrong's request was Stuart Rendel, who as the London manager of the Elswick firm had conducted several business dealings with foreign governments. Rendel was later to recall that he 'never spent a more refreshing and enjoyable holiday than (sailing) to and from Aswan. There we stayed a fortnight and I helped in the survey'. (Hamer, p. 38).

At the end of the visit, Rendel described how comprehensive plans were prepared at Elswick for a ship - railway over the cataracts, worked through turbines driven by the cataracts themselves. Ships which were drawn up an incline by hydraulic power descended on the other side by gravity. According to Rendel, 'the whole scheme was perfectly practicable and I daresay might be carried out even now with the more ease (since) the new and successful barrage has been erected on the same spot'. (Hamer, p. 38). Although the British engineers were 'sumptuously entertained at the Khedive's expense', they actually paid for their hospitality by accepting no remuneration for their professional services.

Rendel's account of the visit barely conceals his suspicion and utter contempt for the Khedive, especially when he pondered 'what a man like Charles Gordon would have thought of a man like Ismail can scarcely be conveyed in language. No two men could have been in more violent contrast'. (Hamer, p. 39). In his description of Gordon and his brothers, Rendel makes a passing reference to 'my good friend' Sir John Adye. Notably in this context, Adye's daughter was to marry Armstrong's great nephew and heir, William Watson-Armstrong, and thus become the first Lady Armstrong of the second creation of the title as Baroness Armstrong of Cragside and Bamburgh.

As was his wont, Armstrong himself, on returning to Newcastle from Egypt shared his experiences with the members of the Literary and Philosophical Society. The four lectures, describing his journeys and the antiquities along the Nile, were given in the winter of 1873 and published in 1874. As at Armstrong's previous lectures, the hall was 'crowded to the doors'.

Previously, he had not travelled beyond the boundaries of Europe, so his own enthusiastic descriptions of the memorable sights of Egyptian life; of Memphis and Thebes; of the temples of Karnak; of the tombs of the Valley of the Kings plus his description of his visit to the Khedive were duly shared with his appreciative audience at Newcastle in 1873. The lectures were published in a small volume of which it has been said:

'The book is full of information, well arranged and written with remarkable clearness and felicity. And I have again read it, after a lapse of ten years, with all the interest of novelty and fresh revelation'. Moreover, 'that characteristic of (Armstrong's) mind to go to the root of the subject is manifest upon these pages'. (E.R. Jones, pp. 29-30 passim).

Travelling from London to Brindisi by way of Paris, Turin, Rome and Naples, Armstrong arrived in Egypt on 17th January 1872, "in company with a friend" - presumably Stuart Rendel - who was with him at every subsequent stage of the tour. His first glimpse of "camels and turbans and palm trees and dark skinned men clothed in many coloured garments was like entering a new life". (W.G. Armstrong, A Visit to Egypt in 1872, 1874, p. 1). At each stage, Armstrong not only described his journeys in graphic detail, but outlined a brief history of the places he visited, so that the modern reader can share, with his audience, his enthusiasm for the sights of an ancient civilisation.

Alexandria, he noted, was not entirely an oriental city because the lure of commerce from Europe and Asia attracted many other races, notably Christians and Jews. The city, he observed, possessed none of its ancient grandeur, "reminding one in many respects of Wapping, and one looks in vain for any remnants of that love of philosophy and literature for which it used to be so famous". (Armstrong, p. 2). Although the ancient city had entirely disappeared, after centuries of violence and pillage, the fine natural harbour was being extended and improved, under the Khedive's orders, by the installation of modern engineering works. In consequence, Armstrong maintained, "the singularly favourable position of the place for commerce seems destined to make the modern city rival the old in commercial importance". (Armstrong, p. 3). From Alexandria, he travelled to Cairo by railway - a distance of about 120 miles. This city, he noted, was very large, having a population about twice that of Newcastle and Gateshead. (Armstrong, p. 7).

During his lectures, Armstrong not only noted the architectural details of the places he visited, but also their religious and social customs. Indeed, many of the points of interest which he emphasised are, like the highlights of his Presidential addresses, still making headlines today. For instance, in describing the schools of Cairo, he noted that the basis of their teaching was the Koran. "Mohammedanism", he observed, "is the religion of a book, and it is surprising what a hold that book has upon the people, irrespective of priestly influence. The Koran appears to be riveted on the nation and I doubt whether anything would displace it, short of a change of race". Then in words which are all too devastatingly being fulfilled today, he added: "It came by force and it will probably never go unless by the same agency". (Armstrong, p. 12).

While he was in Cairo, he went shopping in one of the bazaars, where he soon became adept not only in bargaining, but in ensuring that he was not cheated in the process. "I was very nearly swindled", he recalled, "by a rascally Persian who kept back the best thing he had sold me, in the hope that I would not open the package before I left Cairo and who, on seeing me return to the bazaar with anger on my brow, came out to meet me with bows and smiles and an assurance that he had just discovered that one of the articles I had bought had been by accident omitted". (Armstrong, p. 11).

Armstrong's descriptions of the societies he visited and of the sights he saw were rapier sharp, albeit at times constrained by the prejudices of the British Victorian.

"Dervishes are not priests but laymen", he noted, "following the ordinary occupations of life on working days. They are supposed to be of peculiar sanctity and are highly reverenced by the people. Many of them look like charlatans, but others quite the reverse. I feel confident that the grand old fellow who presided over the miscalled howlers was not only thoroughly sincere, but was every inch a gentleman. Had he been born in a Christian country, and of Christian parentage, his devotional tendency would have taken a better form; but imbued with the tradition of his race, and excluded from all contact with Christianity, except in a degraded form, how could he be expected to take the Bible for his guide instead of the Koran". (Armstrong, pp. 25 - 26).

Like other visitors to Egypt, Armstrong viewed the Pyramids, which he described as "those ancient monuments which more than any other have attracted the attention and excited the wonder of travellers". (Armstrong, p. 41). Although he observed that the great Pyramid was "perhaps the most perfect in Egypt", it was in a more dilapidated state than he had expected to find it. "The finely dressed stones with which it was originally faced have all been stripped off, leaving the present surface very rugged and broken. To me, the Pyramids were more imposing when viewed from a distance than close at hand".

After climbing the great Pyramid, he admired the view from the top. "I know of no situation more calculated than this to carry back the mind to the depths of historical time", he mused. Unfortunately, like all travellers in Egypt, he was pestered by the ubiquitous Arabs and their perpetual cry for 'backsheesh', so that his reverie was broken and he "could meditate on nothing". (Armstrong, p. 43).

Armstrong left Cairo and travelled by rail 156 miles to Minya from where he was to sail up the Nile with "Mr Fowler's expedition to the cataracts on a steamer and a Dahabeeah provided by the Khedive". (Armstrong, p. 79). The Dahabeeah, which "was a vessel of native build, graceful in form and gaily painted red and green", obviously fascinated Armstrong. It was a hundred feet long and twenty feet wide. There were seven cabins all on deck, as well as saloon and bathroom facilities. "Rigged like all Nile boats with lateen sails, (it) was like a bird upon the water". (Armstrong, p. 80). By contrast, the steam boat was of English build, powered by engines made by Robert Stephenson's firm in Newcastle. According to Armstrong: "In the two vessels, we had 43 persons to attend upon and escort just 4 Christian gentlemen. Our stores of provisions were boundless. Truly the Khedive is no niggardly provider. --- Thus equipped, we commenced our voyage up the Nile, the steamer towing the Dahabeeah". (Armstrong, p. 81).

After describing his visit to Thebes, he spoke of the climate of Nubia, which he considered to be superior for invalids to that of Egypt, and continued:

"At the end of our day's sail we stopped for the night at a point which lies almost precisely under the Tropic of Cancer. It was a lovely evening; and indeed the evenings are seldom otherwise on the Nile, especially on the higher parts. When the sun goes down, the heavens become full of glory. First comes the zodiacal light - rarely seen in England - but which, in the absence of the moon, we saw every night on the Nile. It looks like a great comet's tail, the broader end touching the horizon where the sun has disappeared, and the smaller end reaching far up into the spangled sky. As the darkness deepens, the zodiacal light diminishes and soon disappears, while the Milky Way comes out with extraordinary clearness. The stars shine with a lustre seldom witnessed in England, and appear in places where we are not accustomed to see them. New constellations also come into sight as we journey southward, and when Nubia is reached the Southern Cross first becomes visible. So clear is the air, that the satellites of Jupiter can be seen by some clear sighted people with the naked eye. I cannot verify by my own experience, but with a common low-powered opera glass I could see them perfectly". (Armstrong, p. 160).

Despite the popularity of his lectures as evinced by the capacity audience on each occasion, one of Armstrong's biographers sugggested that: 'He is not an orator, but he is always listened to with the closest attention. A master of his subject, with a clear, precise method of speech and a quaint vein of humour breaking through the surface at intervals, make him an interesting not to say fascinating speaker'.

(E.R. Jones, pp. 28- 29).

Some years earlier, the venue for these lectures had been another instance of Armstrong's generosity to Newcastle. For some time, the popularity of the lectures of the Literary and Philosophical Society had highlighted the urgent need for a new lecture theatre, so the Committee proposed to set up a trust fund for this purpose in 1857. Although they were at pains to ensure that the Society did not incur any undue debt, they commissioned plans for the room to be built on the vacant land behind the Society's premises. (Lit & Phil Sixty Fifth Report, p. 4). Equally important in the context of Armstrong's generosity was a reference in the same Report to 'the most valuable donation received from Mr. W.G. Armstrong, one of the Vice Presidents'.

His father, who had died in 1857, after having held the office of Mayor of Newcastle in 1850, had expressed the wish that:

> 'The Society should be invited to select from his library such scientific works as it did not already possess. At the request of Mr. W.G. Armstrong, the selection has been made by the Librarian, and the result has been that the Society is now in the possession of no less than 1,284 distinct works in volumes and tracts thus selected. These works are not only intrinsically valuable, but many of them extremely rare and curious. This addition to the mathematical works already belonging to the Society makes this Society's collection of mathematical works more complete than that of any provincial institution in the kingdom. Besides scientific works, this donation includes other works in various departments, and a large collection of local and other tracts. The members will duly appreciate alike the public spirit which dictated this generous offer on the part of Mr. Alderman Armstrong and the liberal manner in which his son has carried out the wish of his lamented father'. (Lit & Phil Sixty Fifth Report, p. 6).

Not content with having fulfilled his father's wishes regarding the Society's library collection, Armstrong himself showed great generosity of spirit respecting the new lecture theatre. As the need for better accommodation became still more acute, the Committee had experimented, apparently unsuccessfully, with holding the lectures in the New Town Hall. Reluctantly, 'the result convinced the Committee that it is desirable for the future to continue with the lectures within their present building until the Society shall be able to provide a proper room for the purpose'. (Lit & Phil Sixty Sixth Report, p. 6).

Fortunately, they were able to report that a solution was readily to hand.

'Mr. W.G. Armstrong, one of the Vice Presidents, through the Treasurer has intimated that it is his intention to place the sum of £1200 at the disposal of the Committee for the purpose of providing a suitable lecture Room'. (Lit & Phil Sixty Sixth Report, p. 6).

The Society's official history continues the story of Armstrong's involvement:

> 'The site and plans were to be approved by an architect appointed by Mr. Armstrong, and the Society entrusted the task to Mr. Dobson. After his plans had passed a special meeting of the members, they were accepted by Mr. Armstrong, and the work was carried on so speedily that, in spite of the illness of the architect and the severity of the weather, in 1860 the room was ready for use. The generous donor had become Sir William, and President of the Society. He wished to have mahogany instead of deal seats, and this with the cost of painting, furnishing, etc., raised the expense considerably above the estimate. Sir William sent the Society a cheque for £1450, which more than defrayed every charge, including the architect's fee'. (Spence Watson, p. 131).

After noting that this was not the first occasion on which the Committee had to record Armstrong's liberality, they adopted a resolution 'expressive of the warmest gratitude and best thanks ---- for this latest munificent act of his towards the Society'. (Lit & Phil Sixty Seventh Report, p. 4).

Naturally, Armstrong was able to test to the full the amenities of the new lecture theatre when he was invited to speak on his visit to Egypt. By that time, he was President of the Literary and Philosophical Society of Newcastle upon Tyne - a post which he held from 1860 until his death in 1900. He succeeded Robert Stephenson, whose untimely death at the age of 56 caused the vacancy and robbed Tyneside and Britain of one of their most outstanding engineers. Armstrong was President of the Literary and Philosophical Society at the time of its centenary celebrations in 1893. While giving a lecture on electricity at that time, he recalled that his father was among the earliest members of the Society a century earlier, and he, himself, was lecturing to them at the time of their golden jubilee. (W. Watson Armstrong, 1896, pp. 491-2). Of Armstrong's rôle, it has been said: 'The Literary and Philosophical Society of Newcastle upon Tyne is indebted to Sir William Armstrong, its President, for more than his bountiful hand and wise supervision. His lectures from its platform have added to the high position it occupies among the societies of England'. (E.R. Jones, p. 28).

Active though Armstrong was, in the affairs of the wider community, he was, by no means, acting alone. North East organisations like the Newcastle Literary and Philosophical Society and the North of England Institute of Mining and Mechanical Engineers were pioneering schemes for the furtherance of scientific and technical education, which continue to benefit the region and the country even today.

CHAPTER IX.

FIERY PITS AND SPORADIC ENLIGHTENMENT.

The demand for technical education came from a variety of sources, not least from industry in general and mining in particular. As the pace of industrialisation quickened, the need for coal increased accordingly. Supply could only keep pace with demand by mining more deeply underground and, as in the case of the Cumbrian and Northumbrian mines, under the sea itself. Where mines were dug below the water table, or beneath the sea bed, flooding became a serious hazard.

Soon the task of pumping out the water was a major operation. In one pit alone, 500 horses were employed to remove the water bucket by bucket. (Landes, p. 97). Logistically, and economically, this situation could not continue indefinitely. Thus it is in this context that the work of Watt, George Stephenson and especially Armstrong and Sopwith at Allenheads, assumes a new importance.

Pumping engines and locomotives had one great advantage over human or horse power. Both were tireless and took less space per horse- or man-power unit than the equivalent number of horses and men.

In 1800, the United Kingdom was using 11 million tons of coal per annum. By 1830, the amount had doubled. Fifteen years later, it had doubled again and by 1870 it had reached 100 million tons. (Landes, p. 98). This prolific consumption was due not only to the increasing demands of industry, but also to the inefficiency of the early steam engines and domestic grates - as Armstrong repeatedly observed in his Presidential addresses to the British Association and the professional institutions.

As with other educational reforms, the voluntary principle was paramount in the provision of technical education applied to coal mining, and resulted in facilities which were as inadequate as they were unevenly distributed. (Landes p. 344). Although Armstrong was not specifically concerned at this stage, a study of the ensuing chain of events is essential to a deeper understanding of his eventual involvement with the College of Physical Science.

The movement began to gather momentum about the middle of the nineteenth century, with the establishment of the Royal College of Chemistry in 1845 and the Government School of Mines in 1851 with Sir Henry de la Beche as Principal, Warrington Smyth as mining geologist and Lyon Playfair as lecturer in applied chemistry. In 1835, de la Beche had suggested the establishment of a Museum of Economic Geology while instigating a Geological and Mining Survey of Great Britain. The records of the latter were housed in the Museum of Economic Geology which opened in 1837 for that purpose. (Cardwell, p. 87).

Nor, in this regard, should the pioneering work of Thomas Sopwith be overlooked. His mining work, along with occasional railway surveys aroused his interest in geology, while his association with William Smith, the founder of stratigraphical geology, extended his knowledge and concern to such an extent that, after the meeting of the British Association in Newcastle in 1838, he was instrumental in inducing the Government to found the Mining Records Office. From 1839, this became the national depository for all records pertaining to mining operations in the country. In a paper presented to the North of England Institute of Mining Engineers, he repeated 'the opinion I have often expressed that a correct and methodical system of keeping mining records is worthy of further attention, not only on the part of individual proprietors but on the part of the Legislature, for the public benefit'. (T. Sopwith, "On the Lead Mining Districts of the North of England", Transactions of the North of England Institute of Mining Engineers, Vol. XIII, 1863-4, p. 198). Through his mining surveys in Ireland and his experiences in developing the Belgian Railways, Sopwith realised the scientific importance of recording those geological features exposed by the excavation of railway cuttings. On his initiative, the British Association made a grant for that purpose in 1840. (D.N.B. Vol. LIII, 1898, sub Sopwith, p. 263).

Even by 1870, the paucity of technical education was still giving cause for concern. London University failed to meet the demand and even Durham - located as it was in the centre of one of the country's largest coalfields - was the subject of a Government enquiry in 1862. Owen's College in Manchester was established in 1851 and in the same decade University degrees in science were introduced. Nonetheless, in the context of this study, the most important advance was the establishment of the North of England Institute of Mining Engineers, in Newcastle in 1852, only a year after the opening of the School of Mines in London. Not only was this the first Mining Institute in the country but, primarily in this context, its members worked tirelessly for the establishment of a College of Physical Science in Newcastle which became part of Durham University and later bore Armstrong's name.

The laissez faire attitude to popular education is well known. What, then, prompted the mining engineers to make provision for technical education applied to their industry? Apparently, the spur was necessity, allied to economics, rather than philanthropy on the part of the coal owners. Throughout the history of coal mining, and certainly from the days of the Stuarts, explosions from 'choke damp' or 'fire damp' were a constant hazard in a miner's life. (Middlebrook, p. 88). Moreover, gunpowder, which had been in regular use for quarrying stone, was increasingly used to blast coal. The depth of the northern pits and their 'prodigiously fiery' character, increased the risk of explosions. Not surprisingly, between 1815 and 1855 there were several serious accidents in the Northumberland and Durham coalfields. Of these, the two worst were at Wallsend in 1835 when 102 lives were lost, and at Haswell in 1844, when 95 men and boys were killed. (Middlebrook p. 187). Again, when ponies were introduced in the northern collieries, about the mid - eighteenth century, to draw sledges of coal along wooden railed tracks, small boys were employed as drivers. By the early nineteenth century, the hours worked by the boys greatly exceeded those of the men and was a contributory factor in mining accidents. (Middlebrook p. 106).

Increasing demand brought the need for improved transport. The wooden rails and sledges were gradually replaced by iron rails and waggons which, with the development of the steam engine, paved the way for the locomotive and the opening of the Stockton to Darlington Railway in 1825.

Before the establishment of the Royal School of Mines, there were no mining schools in the country, apart from sporadic attempts in Cornwall and elsewhere. Considering the vast wealth created by the mining industry, this was a sad reflection on those concerned, especially in view of the heavy loss of life often caused by ignorance of the most basic scientific principles. Mining, like other trades, relied on the apprenticeship system to teach essential skills to young people. Unfortunately, because mining operated in small units in isolated places, it was not even considered necessary for a manager to be able to read or write. Under these circumstances, formal education was an irrelevance and classes to augment practical training were rare. (J.K. Almond, "British Technical Education for Mining - an Historical Survey to 1920. Part I Progress to 1872". Transactions of the Institution of Mining and Metallurgy, Vol. 84, Section A, 1975, p. A60).

However, there were exceptions to this rule, the most noteworthy in this context being the lead mines and smelting companies of the northern Pennines. The richest mining field was at Allenheads and had been owned and developed by the Blackett family since the reign of Charles II. It was here that Sopwith was later appointed agent and sought Armstrong's advice on hydraulic machinery.

The mines in upper Weardale, upper Teesdale and Alston were leased from various owners by the London Lead Company. Unlike many of its contemporaries, the success of the London Lead Company rested both on the adoption of sound technical processes which were constantly under review, and a commitment to research and development. (Arthur Raistrick, Two Centuries of Industrial Welfare; The London (Quaker) Lead Company, 1692-1905, 1977 edition, p. 11). Indeed, the social and educational work of this Quaker firm is noteworthy, not so much because it is in stark contrast to the general attitude of other employers of the time, but because it was operating in the region under review. Thus it is a useful yardstick against which to measure the work of both Sopwith and Armstrong.

The London Lead Company built schools for their workers' children at Nenthead and subscribed to the existing charity schools in other villages where the miners lived and worked. Nor was the education of the workers neglected. It was the Company's practice to send their employees to different branches of the firm to study the best methods and to undergo such further training as would qualify them for promotion. By this means the smelt mills near Middleton in Teesdale became the training ground for smelters and Nenthead for miners and surveyors. (Raistrick, p. 66). It is in this context that the work of Sopwith and Armstrong should be assessed.

For example, when Sopwith was appointed chief agent at Mr Wentworth Blackett Beaumont's lead mines at nearby Allenheads in 1845, he did not confine his duties to those of a mining engineer. He superintended the erection of workmen's dwellings and even organised a local system of education including and schools and libraries, as well as benefit societies. (D.N.B. sub Sopwith, p. 263). Moreover, when the Association for the Advancement of Social Science met in Newcastle in 1870, when Armstrong was present, Sopwith read a paper on "Education in the Mining Districts in the North of England". Arguing that 'his experience convinced him that scientific instruction would greatly aid miners in their work', he suggested that elementary education was needed for the children of miners at least up to the age of ten, and that they 'should be instructed thoroughly in the operations connected with a mine'. In addition to a laboratory for chemistry, he argued that: 'well-selected teachers should be engaged in teaching hydrostatics and mechanics'. Notably in the present context, he averred that: 'the University of Durham could afford to encourage this kind of education and to provide the advantages of a good museum'. (Transactions of the National Association for the Promotion of Social Science, Newcastle meeting, 1870, p. 349). Although no evidence has yet been found to substantiate this, it seems reasonable to suppose that the example of the London Lead Company, operating in such close proximity, could have had a powerful influence on Armstrong. Mindful that the Elswick Works opened only two years after Sopwith went to Allenheads, and recalling the friendship of these two, during the negotiations for the Whittle Dean Water Works, could Armstrong, too, have been influenced by the Quaker example? Certainly, the concluding remarks of Sopwith's paper to the North of England Institute of Mining Engineers on the Northern Lead Mines, give such a hypothesis a measure of credance. Observing that his own employer, W.B. Beaumont, had improved the mine workings by introducing a series of shafts which, ultimately, would be about seven miles in length, Sopwith continued: 'At three of these shafts and also at the Allenheads mines, are several extensive adaptations of improved hydraulic engines invented by Sir William Armstrong'. (Transactions N.E.I.M.E., Vol. XIII, 1863 - 4, p. 198). With such a level of involvement with the region's lead mines over a protracted period of time, it could be argued that the Quaker example was Armstrong's inspiration when he built houses for his workmen, schools for their children, and actively encouraged the development of the Mechanics' Institute at Elswick, from the inception of the Works.

Meanwhile, what was happening in the North of England generally? Writing of the scene in the 1830s, Almond observes:

'Newcastle's position as the regional centre of the important Northumberland and Durham coalfield and with an employers' organisation The Coal Trade Association already in existence, would have made it eminently suitable as the North of England leader in mining education, but educationally, nothing materialised from this leading position for another 20 years'. (Almond, p. A62).

In the context of any major initiative like the North of England Institute of Mining Engineers or the College of Physical Science, that was true, but other developments were taking place, from within the industry itself, albeit hampered by lack of funds and sponsoring patrons.

Most of the proposals centred around the need for improved safety in mines. Thus, for those who worked in the industry, education leading to safer conditions underground was, literally, a matter of life and death. Perhaps the earliest recommendations came in the report of the Sunderland Committee formed in 1812, to investigate the causes of a serious explosion at Felling Colliery, County Durham, on the 25th May of that year.

A further spate of recommendations came in the 1830s. During his evidence before the Select Committee on Accidents in Mines of 1835, George Stephenson argued that safety in mines was of such national importance as to justify the appointment of a Government Inspector 'to take care of all mines and inspect them with reference to their safety'. In the event such an appointment did not take place until 1850. (W. Widdas, "Improvements in Mine Safety Since 1871", The Mining Engineer Vol. 131, 1971 - 72, p. 255).

Meanwhile, the death toll in the pits continued unabated, drawing the attention of a reluctant public to the ceaseless dangers facing the miner in their daily tasks. In the context of Armstrong's involvement with the College of Physical Science perhaps the most noteworthy accident occured in 1839 when an explosion at Saint Hilda's Colliery, South Shields, caused the deaths of 52 men and boys, and led to the formation of the South Shields Committee. Indeed, its members applied themselves so diligently to investigating the causes of mining accidents that their deliberations could be seen as a watershed both in the history of mining and of technical education. So important did Nicholas Wood consider their findings that he alluded to them in his inaugural address to the North of England Institute of Mining Engineers. (Transactions N.E.I.M.E., Vol. I, 1852-3, p. 18).

Like others at this time, the Committee compared the paucity of the scientific and technical education of mine officials in Britain with that in Europe where 'mining schools had long existed while (we were) now only beginning to endeavour to meet the necessity under the efforts of private individuals and institutions'. In a remarkably visionary move, the Committee not only appealed for structured courses applied to mining, but, in 1841, they met with members of Durham University to further this end. (F.B. Hinsley, "The North of England Institute of Mining Engineers and the Establishment of the College of Physical Science, Newcastle upon Tyne, in 1871", The Mining Engineer, Vol. 131, 1971 - 2, p. 30). It should be noted that Professor Hinsley's lecture formed part of the Centenary Celebrations of the College of Physical Science in 1971. Appropriately, the venue was the Department of Mining at the University of Newcastle upon Tyne which, originating in Durham University, was the first such university department in the country. Even so, there was a considerable time lag between the proposals of the South Shields Committee and their eventual realisation.

Despite this apparent lack of enthusiasm, there were some encouraging signs. Most notably in the present context were the serious discussions between representatives of the South Shields Committee and the Senate of Durham University.

The South Shields Committee produced a series of recommendations so comprehensive and visionary that the Government Select Committee, reporting on Accidents in Coal Mines, included them as an Appendix to their own Report in 1852. The wide ranging South Shields Report covered every aspect of the pitman's employment, including codes of practice designed to ensure safer working conditions in the mines. Like many of their more enlightened contemporaries, the Committee compared mining practices in Britain with those of other countries:

'It is surprising that the coal mines of Britain, so vital to her strength and prosperity, should be left to the unassisted efforts of individuals without organisation, or even the supervision of the State, while those of other countries, from the earliest periods, have received the particular attention of their respective Governments'. (The Report of the South Shields Committee Appointed to Investigate the Causes of Accidents in Coal Mines 1843, p. 66).

Thereupon, they pressed for greater Government involvement in mine safety by showing that precedents already existed where such measures were in the interests of public safety.

'The legislature has already been induced to authorize a continued Government inspection of the railways, and has interfered for the benefit of society for the freedom of trade in the practice of medicine, law, innkeeping etc. Therefore, this Committee cannot but feel assured that, on similar principles, a modified public supervision and control over mining operations, which implicate so largely the prosperity of the country and the safety of the people, are equally just and reasonable'. (South Shields Report, p. 68).

Their recommendation for Government inspection in mines was finally realised in 1851.

Like Sopwith and Armstrong, the Committee paid considerable attention to both the 'serious omission' of registered plans and sections of mines and to the eventual exhaustion of Britain's coal supplies. Among other matters, they included the need for caution in the use of safety lamps; the need for correct medical treatment after explosions and the undesirability of employing women, girls and young boys in mines. The Committee agreed that the upper echelons of the mining hierarchy should be able to receive an appropriate education. They claimed that 'every viewer and underviewer (or the chief directing and superintending officers of mines) before they can be legally employed in such onerous and responsible situations where lives and property are so extensively concerned, like medical men and navy officers, should be specially educated for their profession'. (South Shields Report, p. 64).

Moreover, in addition to the better education of the young mining officers, they urged that:

> 'For facilitating the introduction of sound principles of mining, both productive and economical, and for the protection of the workmen, it is necessary to employ well informed scientific and practical inspectors to pay frequent periodical visits to the mines, registering official suggestions and recommendations and on their non-adoption, fully or partially, by an appeal to an authority, which could entertain the whole question judicially, to enforce, if necessary, under certain penalties, their execution and operation; and thus would mining receive the full benefit of the advancing knowledge of the times'. (South Shields Report, p. 79).

In outlining their proposals, they considered that 'a competent knowledge' of the following subjects was essential:-

Mathematics and Practical Surveying; Mechanics; Hydrostatics and Hydraulics; Pneumatics; Chemistry; Mineralogy; Metallurgy; Geology.

Valuable as these general recommendations were in the history of mining and technical education, most notably in the present context was the Committee's realisation of the importance of Durham University in furthering their aims. The place of the University was to prove both an inhibiting and a unifying factor until the College of Physical Science was finally established.

For their part, the Committee agreed that a miner's professional education should be completed not, as hitherto, solely on site, but 'by a course of practical engineering and mining in some fitting institution in the heart of a mining district'. (South Shields Report, p. 64). Thus, at last, it seemed that the gap between theory and practice - between industry and the academic - was to be bridged. Moreover, they noted that: 'it is fortunate for the coal mines that a very valuable institution already exists in the North, with machinery in operation, which, by being somewhat extended, and a practical engineering and mining professor appointed, would fully accomplish this great desideratum'. They further argued that: 'The University of Durham is situated in the very centre of the great coal mining district and is easily accessible from all directions. (It) is already adapting itself to its position and encouraging ------ a better system of education amongst the directors of mines'. (South Shields Report, p. 64).

However, they refined their plans by conceding that certificates of attendance rather than by the examination of approved courses of study at one of the Royal Colleges or Universities of Britain would be acceptable. Thereupon they advanced their recommendations when the Committee met with the Warden and Senate of Durham University, as the Senate Minutes show:

'At a meeting of Senate - present the Warden, Professor Chevallier and Mr Whitley, Junior Proctor.
The Members of a Committee for investigating Accidents in Mines from South Shields attended at their own request and held a Conference with the Senate. Their object was to extend the system of instruction to Civil Engineer Students to those persons who should have the superintendence of mines and the means which they suggested were to establish a Professorship of practical Engineering. It was deemed important that some provision should be made by scholarships or otherwise for the encouragement of students. The Professor of Mathematics was directed to draw up a statement expressing the willingness of the University to co-operate, providing the pecuniary means are raised'. (Senate Minutes, University of Durham, 24th February 1841).

According to a Government report, 'the result of that interview was in the highest degree satisfactory'. (Report from the Select Committee on Coal Mines, 1852, Appendix IV, p. 200). This is not surprising, for not only was the South Shields Committee in favour of the scheme, but the Warden of Durham University, Archdeacon Thorp, had expressed similar views some years earlier:

'The vast and increasing amount of capital invested in works connected with the existing and projected Mines and Railways and Harbours, is rapidly calling into requisition the services of a class of men who (in this country at least) have hitherto been furnished with very inadequate means of acquiring the theoretical as well as practical knowledge essential for the furtherance of the highly important interests entrusted to their direction. Germany, Prussia, Sweden, France and Spain have all established mining schools'. (Thorp Correspondence 19th December, 1836).

The University's position was outlined in a letter from Professor Chevallier. (See Appendix VII). Meanwhile, the South Shields Committee recommended that:

'With the addition of a Chair of Practical Engineering and Mining, and unrestricted permission for young officers of mines to attend the lectures of this and any of the requisite scientific courses, the Committee consider that the University of Durham would offer great and peculiar facilities for this important object. For practising the profession of an engineer of mines, the Committee then deem it necessary that a sufficient course of mathematics and practical surveying, mechanics, hydrostatics and hydraulics, pneumatics, chemistry, mineralogy, metallurgy and geology, should be received at any of the Universities, from which should be obtained certificates thereof, before the admittance of the aspirant for the completion of his professional education, by a course of practical engineering and mining at Durham University, whose certificate should be imperative before permission to assume this responsible situation be accorded. Thus would mining be elevated to a certain, scientific profession, with all the appliances of existing knowledge and experience of the day, instead of the rude, uncertain unsystematic and dangerous art which it now is'. (South Shields Report, p. 66).

Thus, it could be argued that the education of the miners - particularly those in supervisory positions - was the greatest contribution to technical and higher scientific education made by this enlightened committee. Moreover, it could equally be argued that, despite the protracted negotiations and regrettable intransigence already noted, the recommendations of the South Shields Committee were eventually realised, some thirty years later, with the formation of the College of Physical Science in Newcastle, in 1871.

Meanwhile, the unsuitability of many colliery managers and overseers for their responsible positions continued to cause concern, especially in the context of serious accidents due to negligence. Nonetheless, legislation was slow in coming, although serious explosions did arouse the conscience of both nation and government. Playfair was among those who foresaw the need for a highly trained inspectorate with suitable scientific, technical and practical qualifications. Opposition to such intervention came from both Houses of Parliament where the coal-owners, naturally, had much greater influence than those who worked at the coal face. Nonetheless, the adverse publicity given to the recurring accidents and the unfavourable reports from the eminent men heading the inquiries, forced the opposition to withdraw. When the reports, like those of the South Shields Committee added positive recommendations to their criticism, the Government was forced to act. In consequence, a Committee of the House of Lords was appointed in 1849 to inquire into 'The Best Means of Preventing the Occurrence of Dangerous Accidents in Coal Mines'. The result was the passing of the Mines Inspection Act of 1850 and the appointment of four qualified mining engineers as regional inspectors. (Roy Church et al, The History of the British Coal Industry, Vol. III, 1830 - 1913, Victorian Pre-Eminence, 1986, pp. 423 - 424). Their number was increased to twelve in 1855, their appointment being made after an examination by Nicholas Wood 'the prestigious North-eastern mining engineer, viewer and colliery owner' and Warrington Smyth who later became President of the Geological Society. (Church, p. 425). Despite several horrendous accidents in the North-eastern collieries, the northern coalfield appears, on the whole, to have had an exemplary reputation for sound management practices, so much so that H.F. Mackworth, one of the earliest Mines Inspectors, advocated the general adoption of the 'Newcastle system' of management. (Church, p. 426).

The introduction of inspection and the increased agitation for higher safety standards led to the demand for professional mining organisations. Given its historical awareness of the need for high safety standards, it is not surprising that, only two years after the passing of the Mines Inspection Act, the first regional association should be formed in the North East. The North of England Institute of Mining Engineers - later Mining and Mechanical Engineers - was established in Newcastle in 1852. (Church, p. 428).

The Institute, in which Armstrong was to play a notable part, began as a direct result of an explosion in 1852 at Seaham Colliery in County Durham. This mine, owned by Lord Londonderry, was one of many 'fiery' pits in the area and was known locally as 'the Hell Pit' because of its explosive propensities. (J.E. McCutcheon, Troubled Seams, 1955, pp. 40 and 45 passim). Indeed from within three months of its opening, in March 1852, an explosion occurred with a loss of six lives. This was followed by another explosion in April 1864, when two lives were lost and, again, in October 1871, shortly after the founding of the College of Physical Science, when 26 lives were lost. Yet, by far the worst explosion occurred at Seaham in September 1880 when no less than 164 men and boys were killed. (McCutcheon, pp. 39, 62, 66 and 81 passim). None of these distasters compare in macabre scale with that of Hartley, in Northumberland, in January 1862, when 204 lives were lost, yet the Seaham Colliery explosions are singularly noteworthy in the context of this study, since they were the seed bed from which sprang the North of England Institute of Mining Engineers, and thus the College of Physical Science.

With commendable speed, an inquest was held and its findings reported, within a week of the first Seaham disaster. Mr (later Sir) George Elliot recalled that 'immediately after the inquest' a discussion was held during which the constitution of the Mining Institute was formulated. A formal meeting was quickly held in Newcastle on 3rd July 1852. (McCutcheon, p. 46). Some sixteen years after the inauguration of the Institute, George Elliot used the opportunity of his Presidential Address to explain the Society's origins. He observed that: 'since our Institute commenced its corporate life, it has steadily advanced in importance until it has taken its place among the learned and scientific Associations of the country and ---- has become second to none of them in its services to humanity'. (Transactions N.E.I.M.E., Vol. XVIII, 1868-9, p. 19).

In view of the association of Armstrong and Nicholas Wood with both the Mining Institute and the College of Physical Science, the next part of Elliot's address is singularly relevant.

He recalled that:

'The North of England Institute of Mining Engineers originated in consequence of a discussion which took place between ---- some few mining engineers, including myself, immediately after the inquest which followed upon the Seaton (sic) Colliery accident. The various viewers and other authorities who had given evidence before the jury were assembled together and had, as was their habit, been debating as to the causes leading up to these terrible disasters, as well as the best means of preventing their recurrence, when it was proposed that the advantages we were deriving from professional argument and discussion should be extended to the rest of the coal workers in the North of England and that what had then the character of a friendly coterie should become a recognised body, working under fixed rules and with aims which should be clearly defined. The title, regulations and constitution of the Association were all settled in that evening ---- and the present prosperous Society was established'.

'It speedily found favour with all interested in the great mining operations of the country. It promised to supply a want which had not been felt the less strongly because it had not been publicly expressed; and in a few weeks from the inquest --- our Institute held a formal meeting and its rules and principles were approved by the chief mining authorities of the day. We (secured) the services of our late friend Mr Nicholas Wood as the first President, a position he occupied until his death. His well-stored mind and habits of philosophic research were of infinite value to the Institute. From the time of his inaugural address in September 1852 until he was succeeded in 1866 ----- the Institute continued to expand --- until it excelled all provincial associations'. (Transactions N.E.I.M.E., Vol. XVIII, 1868-9, p. 20).

McCutcheon affirms that 'the Institute was a pioneer organisation concerning safety in mines. Incorporated by Royal Charter of 1876 when it was twenty four years old, it became a world influence as a clearing house of technical information on coal mining problems in many countries'. (McCutcheon p. 45). The emergence of the Institute was given full coverage in the Mining Press of the day. As early as 10th July, 1852, the Mining Journal carried not only a notice of the proposed Society but gave a detailed report of 'a meeting in Newcastle upon Tyne of colliery owners, viewers and others interested in the coal trade with a view to the formation of a society having for its objects the diffusion of useful information among the colliery population, the discussion of topics immediately concerned with ventilation and the general scientific details of the winning and working of collieries'. (Mining Journal, 10th July, 1852). A later issue of the same publication gave full coverage of the inaugural meeting held in the lecture theatre of the Literary and Philosophical Society. (Mining Journal, 11th September, 1852).

From the outset, the Mining Engineers had definite views on the future of their Institute. On 3rd September, 1852, only three months after the Seaham Colliery disaster, with eighty members already enrolled, Nicholas Wood addressed the inaugural meeting of the North of England Institute of Mining Engineers as its first President.

'We must each of us act as if we were individually responsible for the success of the Institution; and with such efforts and actuated by such feelings, there can be no doubt that we can be successful'. (Transactions N.E.I.M.E., Vol. I, 1852-3, p. 13).

Wood indicated that the object of the Institute was two fold:

'First, by a union or concentration of professional experience to devise measures which may avert or alleviate those dreadful calamities which have so frequently produced such destruction to life and property and which are always attended with such misery and distress to the mining population of the district; and

Secondly, to establish a Literary Institution more particularly applicable to the theory, art and practice of Mining, than the Institutions in the locality at present, or which are within the reach of the profession in this locality'. (Transactions N.E.I.M.E., Vol. I, 1852 - 3, pp. 13-14).

Thus the Institute was built around the twin pillars of accident prevention and the advancement of Mining Science. Although Wood indicated that they would welcome anyone who would help to further these aims, he emphasised that it was primarily 'an Institution of practical miners'. On the basis of their common knowledge and experience they were committed to prevent 'as much as practicable the recurrence of those dreadful catastrophies ------ and at the same time to raise the art and science of mining to its highest practicable scale of perfection, in safety, economy and efficiency'. (Transactions N.E.I.M.E., Vol. I, 1852 - 3, p. 14).

Nor was the membership limited to working miners. As Wood noted, the support of the coal owners was 'all powerful', and the best interests of all would be served by adhering to the twin aims of the Institute. 'We are all associated together for the improvement of the art of mining scientifically, practically and economically, (thus) the proprietor of the coal, as well as the worker of it, is no less materially interested in the success of the Institution'. (Transactions N.E.I.M.E., Vol. I, 1852-3. p. 15).

Equally, he welcomed the support of 'any literary, scientific or practical members of other Instituions, professions or occupations, whose labours, talents or professional experience can in any way aid our efforts in the accomplishments of the objects of the Institution either in the prevention of accidents or in the art of mining'. (Transactions N.E.I.M.E., Vol. I, 1852-3, p. 15). It was on this basis that engineers and captains of industry like Armstrong and Isaac Lowthian Bell became involved in its affairs.

In concluding his inaugural address, Wood spoke of 'the mainspring of the Society', which, he reiterated, was 'the advancement of science applied to mining'. Sciences like mineralogy, chemistry, mechanical philosophy, pneumatics and mechanics, he concluded, should 'occupy the time and attention of all individual members of the Institution and ---- ought to enter into the education of a mining engineer'. (Transactions, N.E.I.M.E., Vol. I, 1852-3, p. 29). Thus from the President's address at the inaugural meeting, it was evident that Wood and the other mining engineers in the North East were prepared to establish a School of Mines, or similar institution, in Newcastle.

So important did they consider this scheme that at the General Meeting of the Institute, held in Neville Hall, Newcastle, on 1st November 1855, Nicholas Wood indicated that the main business of the meeting was 'to consider the Prospectus and Report of the Special Committee as to the Proposed College of Mining and Manufacturing Science'. (Transactions N.E.I.M.E., Vol. IV, 1855-6, p. 23).

This Special Committee had already been appointed under no less distinguished auspices than a General Meeting of Representatives of the Coal Mining Interests of Great Britain, held in London in the previous July, and by the Coal Trade and Institute of Mining Engineers of the North of England. Their remit was 'the proposed establishment at Newcastle upon Tyne of a College to be entitled the "British College of

Practical Mining and Manufacturing Science" '.

The origins of the Committee and the proposed name of the College indicates that the institution in Newcastle was to be no mere provincial school, teaching the elements of science to miners. Obviously it was to be on a par with the School of Mines in London, or even the polytechnics of Europe. Nonetheless, Wood was at pains to indicate that no rivalry would exist between the establishments in London and Newcastle. Even in his inaugural address, he affirmed that: 'We do not for one moment entertain the idea that the establishment of this institution should, in the least degree, interfere in any way whatever with the establishment of any other Institution for the prevention of accidents in mines and particularly with the one proposed to be established in London'. (Transactions N.E.I.M.E., Vol. I, 1852-3, pp. 16-17).

Thus, both in aim and intent, the Newcastle College had a unique role to play in the advancement of British scientific education. Moreover, as well as interested parties from other districts, Committee members from the North East included W.G. Armstrong, Isaac Lowthian Bell (then Mayor of Newcastle), Thomas Sopwith and Nicholas Wood. (Transactions, N.E.I.M.E., Vol. IV, 1855-6, pp. 23-24).

However, in the context of this study, it should be noted that, notwithstanding his indifference to Greenhow's earlier plans, this was the point at which Armstrong became involved in the cause of higher scientific education in Newcastle. When Greenhow's plans were first mooted, Armstrong, then aged 21, was heir not only to his father's successful corn merchant's business but to Armorer Donkin's legal practice, which was one of the most lucrative of its kind in the North. Understandably a young man in that position had little thought for anything beyond his own personal future. Now, in his mid-forties; an established captain of industry; acknowledged alike by engineers, scientists and lawyers; when the opportunity again presented itself, he gave it his unequivocal support. Right from the outset, he was a member of the planning Committee of the proposed college in Newcastle which, when finally established, bore his name. Alas, despite its early promise, the realisation of this dream was still far in the future. Wood did not live to see it and Armstrong, meantime, faced public humiliation.

Meanwhile, at the General Meeting of the Mining Institute, held on 1st November, 1855, Wood invited Mr T.J. Taylor to read a document entitled 'Prospectus of a College of Practical Mining and Manufacturing Science, proposed to be established at Newcastle upon Tyne'. Not only had this paper been discussed by the Committee of the Mining Institute, but had been widely circulated among other interested parties.

Before continuing with his subject, Taylor noted that:

'It has long been a subject, not only of regret but of surprise that, in a country like Great Britain, which, for mineral wealth and the manufactured products of such wealth, is unequalled by any in Europe, a College of Practical Mining Science should still remain a desideratum'. (Transactions N.E.I.M.E. Vol. IV, 1855-6, p. 24).

Nor, he added, were inquiries lacking from abroad, both as to the probability of the establishment of such an Institution and to offers of practical help and support in such an event. As a result, the North of England Institute of Mining Engineers, whose membership included the mining interests from all parts of England and Wales, had taken the initiative. Not only had they given the matter serious consideration, but had printed a series of 'Suggestions' which had been widely circulated and discussed.

The deliberations ranged around two specific issues:

1. What locality afforded the greatest number of natural facilities for the establishment of such an institution, and for its future efficient conduct?
2. Which branches of science, directly or collaterally connected with mining generally should be taught by such an institution?

In the context of natural advantages, central position and local manufacturing and trading pursuits, Newcastle was 'beyond question --- the site most advisable for such a foundation'. Moreover, an appropriate curriculum should include 'eight distinct branches of teaching which were deemed to be desirable for the purposes of practical engineering as applied to mines whether of lead, copper, tin, iron or coal, as well as for those branches of science which bear upon the most important manufacturing processes'. (Transactions N.E.I.M.E. Vol. IV, 1855-6, p. 24). The project had already been considered by representatives of the British coal and iron mining interests who, assembled in London in May 1854, agreed that:

'It would be of essential service in the future management of mines and ------ in the prevention of accidents, if a central Mining School or College of a practical nature were established in some convenient and suitable colliery district, ----- for the education of mining engineers or other officers ----- entrusted with the management and conduct of the mines of this country. And that the Parliamentary Committee now sitting on Accidents in Mines be solicited to take this subject into their serious consideration with a view to recommending the Government to afford such aid as they may deem advisable and requisite to establish an institution so necessary and laudable'.

Because of this proposal the Committee decided to 'urge upon the Government to foster by grant in aid the establishment and maintenance of Mining Schools in the large Mining districts throughout the country'.

The resolution, in turn, was widely circulated along with the proposals of the North of England Institute of Mining Engineers. This led to a further discussion, the following year, by the Conference in London when the resolution was confirmed 'and the site of Newcastle upon Tyne was named as the most convenient for a foundation of this peculiar nature'. (Transactions N.E.I.M.E. Vol. IV, 1855-6, p. 25).

Naturally, this was a challenge which neither the Mining Institute nor the region, generally, could ignore. As a result, the proposal was raised at the General Meeting of the Coal owners of Northumberland and Durham, who expressed their approval. Taylor then added: 'Such is the shape which the question of a central British College of Practical Mining Science has now assumed, and your Committee now venture to state in detail such further considerations as seem to rise out of the circumstances'.

First, they hoped that all concerned would give the proposals their full support. Moreover, they did not consider the raising of the necessary funds could 'be safely left to spontaneous liberality', but that those concerned should try to obtain either a Charter or an Act of Parliament, which, for a given number of years, would secure the necessary capital.

'Your Committee deem it their duty to express, generally, their warm approbation of the scheme, as sketched in the Report of the Council of Mining Engineers and their hope that the great body of the coal trade will add their efforts to promote, by a resolution this day, this great undertaking, for which all opinions seem to concur in pronouncing this locality to be peculiarly adapted by circumstance as well as by nature, but which is, in itself, of national rather than local importance'.

Prompted by such favourable recommendations, the meeting adopted the following resolution:-

'That the Meeting concurs in the report of the Mining Institute, and in the opinion of the Committee of the Trade, that it is highly desirable to establish a College for the Advancement of Practical and Manuacturing Science at Newcastle, a locality so well adapted for that purpose, and strongly recommend the Trade to support the same; and the Meeting is further of the opinion that Lessors of Mines and the Mining interests generally of this and other portions of the Kingdom, as well as the Government, should be applied to for support to such Institution, the object of which appears to the Meeting one of not merely local but of national importance, bearing as it does upon the increased skill and economy in production and also upon the due security of life and property'. (Transactions N.E.I.M.E. Vol. IV, 1855-6, pp. 26-7)

Taylor then outlined the details of the proposed College which, the Committee trusted, would 'make it efficient as a Central School of the Practical Science of Mining in all its branches, as carried on in the European countries'. The syllabus was based on the assumption that the science of practical mining naturally divided itself into eight compartments:

1. Mathematics
2. Natural Philosophy and Mechanics
3. Mechanics in their application
4. Plan Drawing, Surveying, Levelling, Machine Drawing
5. Mine Surveying
6. Chemistry, Practical and Theoretical
7. Mineralogy and Geology
8. The Working of Mines.

Mindful that this syllabus was compiled by experienced mining engineers, it was, understandably, practically biased. Indeed, it seems more in tune with the vocationally orientated curricula of to-day's technological universities than those of the classically based universities of its own day, or even the commendably visionary syllabus of Greenhow. (See Appendix I).

Having decided on the syllabus, it was agreed that five Professors would be capable of teaching a two year course of six to eight months a year, divided into two or more terms. The course could be extended to three years, and should be flexible enough to enable managers to attend classes on a part time basis.

Essentially the College was to maintain both a scientific and a thoroughly practical character. Moreover, Newcastle, situated as it was, 'in the midst of the most extensive and difficult mining concerns in the kingdom' was a singularly appropriate location, especially in view of the amount of sound practical knowledge available. This, apparently, was a weakness in the much-vaunted continental colleges. Located away from mining and manufacturing areas, their courses were, of necessity, more theoretical than practical.

So practically biased was the Newcastle course to be that no certificates would be awarded until a student had completed 'two years actual experience in the mines or manufactories'. Equally, the Professors and their staff were to be given the opportunity to further their own industrial experience in the mines and manufactories, by mutual agreement with their owners.

Examinations were to be conducted under the direction of the governing body. Fees for admission were to be £20 in one payment or two annual payments for £12 each for the whole course. Separate arrangements would be made for attendance at individual classes, while young miners were to be admitted at specially reduced rates.

Admitting that the Institution should be self-sufficient, the Committee agreed that the initial outlay for the building with its classrooms, apparatus and other amenities, 'will involve the expenditure of a considerable sum'. Naturally it was hoped that the Coal owners and manufacturers would be most forthcoming in this regard, supported equally by the Corporations of Newcastle and the other large towns in the area. Moreover, it was noted that 'there are surplus funds arising out of the mines in the Diocese of Durham' which might, appropriately, be applied to such a cause.

The annual expenditure would, it was estimated, amount to £3,000, while the cost of building - for which an estimate had already been procured - was £16,000. The entire capital, inclusive of all foreseen expenditure, appeared to be about £35,000. Two fund-raising methods presented themselves. First, by obtaining an Act of Parliament, with the assent of all parties concerned, whereby a small percentage charge would be made on all minerals extracted by those included in the Act. Second, by using voluntary subscriptions covenanted for in a trust deed.

Before making these proposals, the Committee had considered the Statistical Returns compiled by the Keeper of Mining Records and presented to the Library of the North of England Institute of Mining Engineers. These details of the entire mineral wealth of the United Kingdom led them to suggest that a colliery vending 6,000 tons a year would only be expected to contribute a mere £2 - 15 shillings towards the cost of the College. Nonetheless, the scattered nature of the collieries presented logistical difficulties for the collection of the money while the opposition of many colliery owners to a Parliamentary Tax posed a real threat to progress.

Assuming that the College would be expected to be self-supporting, the Committee believed that the subscription plan would be the most viable. Nonetheless, at the conclusion of the paper, the President indicated that, if the Meeting adopted the general terms of the proposals, the Committee were still willing to consider further recommendations which would promote the general objects in view. (Transactions N.E.I.M.E. Vol. IV, 1855-6, p. 27 - 31 passim).

The meeting concluded with the adoption of the following resolution:

'That the prospectus read be approved of and adopted, and that it be printed and circulated; and also that a committee be requested to take such steps as may be requisite to procure subscriptions for the establishment and support of the proposed college'. (Transactions N.E.I.M.E. Vol. IV, 1855-6, p. 32).

Given the challenging remit of planning the central British College of Practical Mining Science in Newcastle, the North of England Institute of Mining Engineers were equal to their task. On 6th February, 1856, only three months after Taylor had presented his paper, Nicholas Wood reported to the Institute the commendable progress made to date.

First he expressed his 'great satisfaction in adverting to the very encouraging position in which the project was placed by the munificent offer of His Grace, the Duke of Northumberland'. This was Algernon Percy, fourth Duke of Northumberland who, as Lord Prudhoe, was invited to represent his brother, the third Duke, as President of the British Association in Newcastle in 1838. Thus his interest in scientific education was of long standing. Not surprisingly, from the outset, he was invited to become Patron of the College.

In reply to Wood's letter, the Duke acknowledged 'from experience that the permanency of such institutions greatly depends upon the endowment being adequate to carry them properly forward; especially as regards the procurement of suitable and talented Professors, and therefore recommends this subject to the chief and earliest consideration of the committee'. (Letter from Hugh Taylor, Alnwick Castle, 11th January, 1856. See Appendix VI). As well as agreeing to become Patron of the College, the Duke indicated 'that if £15,000 be raised for the endowment he will contribute £5,000 making £20,000 and if £30,000 be raised he will subscribe £10,000, making £40,000 for like purpose'. (Letter 11th January 1856). The Duke's generous offer, Wood maintained, not only 'reflected infinite honour upon him', but ensured that 'the College would be established upon a most satisfactory scale'. (Transactions N.E.I.M.E. Vol. IV, 1855-6, p. 107).

Copies of the letters, (See Appendix VI), together with details of the proposals 'had been sent to every nobleman and gentleman connected with the coal trade and mining and manufacturing interests of the district, and also to the Members of Parliament representing the two counties of Northumberland and Durham'. Recalling the Duke's proffered donation of £10,000, Wood hoped that others would respond with equal generosity.

But such a visionary plan was bound to create jealousy among established institutions who saw it as a threat to their own existence. The proposed College at Newcastle bore the seeds of the first technological university in the country, and thus attracted criticism, as Wood's Report suggests. Some existing institutions were concerned that their own educational work for the mining and manufacturing professions had not been acknowledged. To this, he emphasised that while no discourtesy was intended, the Committee considered that it was 'best to pursue a perfectly independent course and to keep steadily in view that the Institution was meant to be of a purely practical character'.

The Committee, he continued, favoured the independent course in order that Patrons like the Duke, and other subscribers, might be free to model the Institution 'as they might think best (in order) to accomplish the objects in view and render it of the greatest utility'. Nonetheless, this did not preclude any later mergers with existing institutions when such an occasion arose.

In this regard, Wood recalled that the Duke shared the views of the Committee:

'As regards the particular locality of the proposed College and the expediency or otherwise of appending it to or connecting it with any existing establishment, the Duke would recommend that these subjects should receive most mature and dispassionate consideration as the success and permanency of the intended Institution may greatly depend upon the decision'. (Transactions N.E.I.M.E. Vol. IV, 1855-6, p. 112).

Returning to the practical nature of the proposed College Wood referred to its inter-relationship with the 'Institution of Practical Science in Jermyn Street'. He paid tribute to the work of Sir Henry de la Beche and Sir Roderick Murchison who, as successive Presidents, had 'attained its high standing and eminence'. However, he saw no rivalry between the two establishments since, both in location and ethos, they served a different purpose. Expressing the hope that there would be great co-operation between the two, he not only re-affirmed the practical nature of the proposed College, but stated its aim of instructing both the higher grade colliery and manufacturing students and those in more subordinate positions who might one day aspire to the higher supervisory grades. (Transactions N.E.I.M.E. Vol. IV, 1855-6, p. 112). In this, we find echoes of the policy of the London Lead Company who recruited their managers from all grades of their employees.

Noting that about a hundred letters had already been circulated, to the relevant trades and industries, Wood indicated that the Committee intended to bring their plans to the notice of the Government and the Bishop of Durham as well as to both the Dean and Chapter and the University of Durham.

Thus, everything seemed to augur well for the future. But this was not to be. Despite their own vested interests in a well educated work force, and safely managed collieries, the coal trade did not respond in direct proportion to the Duke's generous offer. Noting that: 'It is for the interest of the trade that such an institution should be formed', Wood wondered whether their hesitation was really due to the depressed state of the industry or sheer indifference on the part of the coal owners.

Whatever the cause, the lack of response meant that they were unable to fund an independent college. Thus they had no alternative than to approach Durham University with a view to a merger. (Transactions N.E.I.M.E. Vol. VI, 1857-8 pp. 200-1).

Mindful of Wood's later evidence before the Durham University Commissioners, it should be noted that, at this stage, his reports repeatedly testify to very cordial relations being established between the University and the Mining Institute. For instance, he claimed that the correspondence exchanged during the early negotiations proved 'that there is every disposition on the part of the University of Durham to associate with us in promoting our object'. (See Appendix VI. Letters Wood and Chevallier). For their part, the Mining Institute were equally candid in their dealings with the University, and had given them copies of all the relevant papers, including the letters between the Duke and the Institute. (Thorp Correspondence, Vol. V, No. 675).

Unfortunately, the University itself lacked the necessary funds to further the cause. Thus, foundering on the rock of economics in either case, the Mining Institute was faced with the dilemma of establishing an independent College in Newcastle or one governed by the Senate of Durham University with its theological overtones.

In the event, a sub Committee of the Institute, including Wood and Robert Stephenson, who was then M.P. for Whitby, met with two Government representatives, Lord Granville and the Northumbrian Sir George Grey, who suggested a compromise. If they could negotiate for an independent College, a merger with Durham University would be desirable, and Government assistance might be procured if an acceptable plan were produced. (Transactions N.E.I.M.E. Vol. VI, 1857-8 p. 203).

By this time, Wood was Chairman of the Mining Association of Great

Britain so his meeting with the Government ministers was not so much concerned with establishing a Mining College in Newcastle as the formulation of a comprehensive system of mining education in which such a College would play an essential part.

He reported the outcome of his negotiations at the General Meeting of the Mining Association of Great Britain, in Manchester on 23rd July, 1857, when Dr Playfair attended as the Government representative. (Thorp Correspondence, Vol. V, No. 677). Thereupon, it was agreed that Mining Schools should be established in the various mining districts in the country and that the education given should prepare pupils for entry to a Central School or College. (See Appendix VI).

The following decision was carried unanimously:

> 'While this Meeting is duly impressed with the desirability of improving the education of (those) engaged in the management of Mines in the U.K. it does not appear that sufficient encouragement has been given by the representatives of the Mining Districts to the voluntary establishment of an independent Mining College to lead (us) to expect an early success in regard to this object. The Chairman therefore (should) be requested to communicate with the authorities of the University of Durham in order to ascertain whether a Mining Department might be established in immediate connection with that University which might, by means of ramifications in the several Mining Districts promote and in some degree supervise local schools'. (Thorp Correspondence, Vol. V, No. 677).

Up to this point, all parties appeared to agree, but it was at this meeting in Manchester that the first cracks began to appear in the superstructure. They were so fundamental as to prove insurmountable.

It was deemed essential that: 'In considering the establishment of the Mining School in Durham the Chairman should give special attention to the objection which would be raised to the scheme by the Dissenters and others as to Theology and conformity to the discipline of the University'. Moreover, it was considered necessary to arrange the residence of the students 'so as to bring the cost of living within the reach of the classes of persons engaged in the management of Mines', and to consider the annual cost for providing examiners for the College and the associated District Schools. (Thorp Correspondence, Vol. V, No. 677).

On 24th July, 1857, the Committee met with Dr Playfair and drew up a list of proposals for submission to the Government and the coal owners. (See Appendix VI). After further discussion it was resolved that the Chairman should ascertain what support the Government would give towards the proposed Mining Schools and Central College. In case of the latter, they wondered whether the Government would support a completely independent College or 'contribute funds towards the establishment of a Mining Section or College in connection with the University of Durham'. In the event, association with Durham was deemed to be the more feasible approach.

Unfortunately, these negotiations and Wood's illness prevented him from keeping an appointment with Archdeacon Thorp, Warden of Durham University and Professor Chevallier, who was responsible for the existing engineering course at Durham. Nonetheless, they later had 'a meeting of an extremely satisfactory nature'. (Transactions N.E.I.M.E. Vol. VII, 1858-9 p. 30). Regular meetings between the two parties continued, apparently on a similarly cordial basis, until 20th May, 1859, when the Committee of the Mining Institute reported that the plan for the establishment of a Mining College within the precincts of the University had been provisionally arranged. (Transactions N.E.I.M.E. Vol. VII, 1858-9 p. 171-177). The Senate of the University agreed that the Regulations for the existing course in Engineering could readily be adapted to meet the new requirements and submitted for the Institute's consideration a list of 'Heads for the Establishment of a Mining College within the precints of the University'. (See Appendix VI).

In this regard, Wood observed that: 'It will be seen that the Mining and Engineering College, though intended to be locally situated within the University, is yet to be conducted upon independent principles, and to be managed by its own governing body'. (Transactions N.E.I.M.E. Vol. VII, 1858-9 p. 174). Lacking the funds to establish a College of their own and having been offered accommodation within the University for this purpose, this proposal at least pointed a way forward. (See Appendix VI, Letter Chevallier to Wood, Durham 10th February, 1858).

As a result, it was agreed that a sub-committee consisting of Wood, Taylor and Bell, should confer with the authorities of the University and with the Government for the successful establishment of the proposed College. (Transactions N.E.I.M.E. Vol. VII, 1858-9 p. 174).

Why was Armstrong, whose firm had so much to gain from the scheme, not more involved at this stage? It will be recalled that from 1854 onwards he was concerned with armaments, and at the date in question he was Engineer of Rifled Ordnance at Woolwich, leaving his own firm at Elswick in the care of his capable lieutenants. Thus although a member of the College committee, his immediate concerns were at Government rather than local level.

Meanwhile, Wood assured the Mining Institute that, under the present agreement, the proposals for an independent College were being strictly adhered to and its essentially practical nature was being safeguarded. Its management was to be controlled by its own supporters, subject only to those regulations concerning discipline, agreed between the College and the University. The aim of both parties was 'to render the whole as perfect a seminary for the instruction of Mining and Civil engineers as possible'. (Transactions N.E.I.M.E. Vol. VII, 1858-9 p. 175).

Thereupon, Wood gave this confident assurance: 'Looking at the manner in which the authorities of the University of Durham have met the subject, there can be no apprehension that any difficulty will exist in the requisite details for completing the arrangement between the University and the promoters of the College. The only difficulty which presents itself is that of funds'. In that regard he hoped that the Duke's generous gift for the endowment of the Newcastle College would be transferred to the proposed College at Durham, and that some of the funds of the University would be appropriated for that purpose. (Transactions N.E.I.M.E. Vol. VII, 1858-9 pp. 175-6). Thus, all seemed set for the establishment, not only of a College but of one of the most ambitious forms of technical education ever devised.

From 1850 onwards, both accidents in mines and Government Inspection were ever constant subjects for Parliamentary Commitees. Thus, the proposed educational plan of the Mining Institute was given full coverage and approval in the resulting reports. But this state of euphoria soon ended. By February 1860, Wood recalled that although Durham University had agreed to 'furnish lecture rooms and provide two professors', it was now considered desirable that the College should have not only five professors but workshops and other practical rooms appropriate to the course. The estimated expenditure would be £5,000 for the workshops and about £3,000 a year for the professors' salaries. (Transactions N.E.I.M.E. Vol. VIII, 1859-60 pp. 20-21).

Wood further reported that, during the Parliamentary session of 1859, the Committee had met with Sir G.C. Lewis, the Home Secretary, who had promised to give the matter his consideration. Moreover, during the passage of the Mines Inspection Bill, several Inspectors had reported favourably on the establishment of a Mining College. Nevertheless, 'without closing the door on any hope of success' Wood was led to understand that 'the state of the finances at this time would almost preclude the Government from affording any pecuniary assistance'. In order to win support, he again raised the matter with the General Mining Association of Great Britain who reaffirmed the original plan.

He then told the Mining Institute that as the Mines Inspection Bill was still under consideration he, together with the representatives of the mining interests of Northumberland and Durham, would continue to urge the Government to further the establishment of the proposed College. (Transactions N.E.I.M.E. Vol. VIII, 1859-60 p. 22). But it was already a lost cause.

At the General Meeting of the Mining Institute in March 1861, he raised the subject yet again. This time, it was almost a valedictory not only for the College but for the University of Durham. He reminded his audience that the present state of the University had been brought before Parliament and that the Home Secretary was to appoint a Commission of Inquiry into its affairs. (Transactions N.E.I.M.E. Vol. IX, 1860-61 p. 86). In a last ditch stand, Wood suggested that a memorial be sent to the Home Secretary reminding him that when he met with representatives of the University and the Mining Institute the previous year, he promised to give the matter 'his serious consideration'. Noting that 'every person knew that meant that it would be dropped altogether until something again occurred to bring it before the Government and the public', Wood thought the time was opportune to resurrect the issue. To this end, he proposed that when the Commission was appointed, it should consider incorporating a Mining College within Durham University, and should provide the necessary funds. Professor Chevallier had already been approached and had indicated that: 'it would be strictly in accordance with the feeling of the University' that the Institute should 'lay their case fully and completely before the Commissioners'. (Transactions N.E.I.M.E. Vol. IX, 1860-61 p. 87). These plans having been unanimously adopted, it appeared that the only stumblingblock to progress was the lack of funding either from public or private sources.

A few months later, Wood reported that the Act of Parliament appointing the Durham University Commission 'included the promotion and cultivation of practical knowledge as well as of divinity'. (Transactions N.E.I.M.E. Vol. IX, 1860-61 p. 251). He further indicated that he and Bell had been invited to give evidence before the Commission, with power to invite other members of the Institute if required. (Transactions N.E.I.M.E. Vol. IX, 1860-61 p. 252).

The Durham University Commission included in its Report a series of ordinances to be observed in the management of the University. The Mining Institute regretted that these 'were not of a nature to excite much hope of the establishment of a Mining College, or of the establishment, by the University itself, of any system of education likely to be of utility to those engaged in Mining pursuits, or by which the sciences more directly connected with mining may be successfully taught'. (Transactions N.E.I.M.E. Vol. XI, 1861-62 p. xi). Nor were the ordinances more acceptable to the authorities of the University, who agreed to petition the Government for their revision. Thus the Committee of the Mining Institute hoped that 'something may yet be done towards the establishment of some system of education applicable to the wants of the mining interests of Great Britain'. (Transactions N.E.I.M.E. Vol. XI, 1861-62 p. xi).

While politicians, industrialists and academics were wrangling over funds, the mining accidents were continuing to take their toll. Ironically the volume of the Transactions of the North of England Institute of Mining Engineers which virtually pronounced the demise of the proposed Mining College through lack of finance, gave full and detailed coverage to the disaster at Hartley Colliery in Northumberland on 16th January 1862 which, with its loss of 204 lives, was 'unparalleled in the mining annals of the kingdom'. (Transactions N.E.I.M.E. Vol. XI, 1861-62 pp. 143 - 157 passim).

But was finance the only reason for yet another abortive attempt to found a College of Science, preferably in Newcastle? Was it purely a matter of economics or was it some inherent jealousy between 'town and gown' - between some of the academics in Durham and some of the industrialists in Newcastle? Certainly, the coal owners had given scant financial support to the plan.

No evidence has emerged to indicate the real saboteurs, but could they, equally, have emanated from the hierarchy of Durham University where a new and virtually independent establishment in the University precincts would present a direct and embarrassing challenge at a time when its own fortunes were at a very low ebb? It will be recalled that, when the plans for the University were first mooted in the early 1830s, Bishop Van Mildert feared the rivalry of 'any mongrel affair in Newcastle'. At that time, discussions ranged around both Greenhow's College of Science and the establishment of the Newcastle Medical School. (Whiting pp. 33, 119 and 120 passim). Moreover, Wood's own evidence before the Durham University Commission seems to affirm this view. When asked how near they came to realising their scheme, Wood replied: 'It was never practically carried out. There was a difference of opinion as to whether the institution should be at Newcastle or Durham, and it fell through from want of unanimity amongst the parties on that point'. (Report of the Commissioners Appointed for the Purpose of the University of Durham Act, 1861, Minutes of Evidence, paragraph 2031).

How far, too, did the Test Acts militate against progress? The University of Durham, like Oxford and Cambridge, was essentially an ecclesiastical foundation in origin, under the direction and control of the Dean and Chapter of Durham. (Fowler, pp. 22 and 27). Thus no one was admitted to a degree in Durham without subscribing to the requirements of the Church of England. (Fowler, pp. 30-31). Not until 1871 were most religious Tests removed at Oxford and Cambridge, and in the same year Durham University decreed that: 'No student who was not a member of the Church of England should be obliged to attend its services and that no religious tests or subscription should be required'. (Fowler, p. 55).

Thus, by 1862, Newcastle - the centre of the country's leading manufacturing region - was, despite two major attempts, without an engineering College. Durham University, in the centre of the country's largest coalfield was, through its failure to attract students on any of its courses, the subject of a Government Inquiry. Armstrong, having tried to revolutionise the science of gunnery, had returned to Elswick a disillusioned man. The price of coal was still being measured in human lives, lost through the failure to understand basic scientific principles. In these circumstances, what hope was there for the region's future or Armstrong's involvement in scientific education?

CHAPTER X.

A FITTING INSTITUTION IN THE HEART OF A COALFIELD?

The decade of the 1860s saw Britain enjoying the material benefits of the industrial lead she had gained over her European rivals from the time of Waterloo to the Crimea. What was Armstrong doing at that time and what effect did Britain's technical advancement have on the founding of the College of Physical Science?

For Armstrong, the decade opened on a note of triumph. From a partner in one of the North's leading legal firms, he had changed career to become one of the premier exponents of hydraulics. His research into the burgeoning science of electricity had led to his being sponsored in his election as a Fellow of the Royal Society by no less an authority than Faraday himself. Having revolutionised the science of gunnery, for which he was awarded a knighthood, he was, by 1860, Engineer of Rifled Ordnance to the Government. For the head of one of the country's leading engineering firms, presidencies of professional societies followed in rapid succession, until he was invited to be President of the British Association during its visit to Newcastle, in 1863. In the following year, he attended the meeting of the British Asociation in Dundee and was awarded the freedom of that town, in recognition of his services to science. (Obituary Notice, Newcastle Daily Chronicle 27th December, 1900). From these heights, when every desired honour and attainment was already his, all that he had worked for was in ruins when the Government renaged on the agreement to make his guns. In consequence, he had reached his nadir by February 1863.

Under such circumstances, many men would have retired from active life, but to William George Armstrong, such trials were merely the springboard to greater glory. Not only did he find solace in building Cragside, but took an increasingly active part in public life. On the occasion of the annual congress of the Asociation for the Advancement of Social Science in Newcastle in 1870, he presided over the Department of Economy and Trade and delivered an address dealing with relations between capital and labour. (Obituary Notice, Newcastle Daily Chronicle 27th December, 1900). The work of the local Natural History Society claimed his attention and his benefaction. In 1860, on the death of Robert Stephenson, he became President of the Newcastle Literary and Philosophical Society - a post he held until he died - and from 1862 - 63, he was a member of the Council of the Royal Society. After 1863, the Elswick firm, which impartially sold armaments to both sides in the American Civil War, expanded and diversified until it reached heights undreamed of hitherto. This expansion continued till the end of the century under Armstong's leadership and the active participation of his able young management team led by Andrew Noble, Percy Westmacott and the Rendel brothers. Elswick maintained its growth under this team even after Armstrong's death, until, at the outbreak of the First World War, the firm, operating on a global scale, had only one rival - Krupps of Essen.

How did this expansion affect Armstrong's attitude to the proposed College of Physical Science? On the surface, such an institution would have provided a welcome opportunity for the training of Armstrong's future supervisors. Yet here, as in many of his decisions, he displays the true characteristics of his Border ancestors. He was overwhelmingly resilient in the face of difficulties, yet obstinately unforgiving in the event of a misplaced trust. (George MacDonald Fraser, The Steel Bonnets, 1971, p. xvi). When he presented all his patents for rifled ordnance to the Government and agreed to have his guns made at Woolwich, knowing that such actions were personally and industrially suicidal, it was an outstandingly generous and unselfish gesture. When within three years, this action rebounded, Armstrong's taciturn Border nature responded. Back to his native fastness he returned; consolidated his position; surrounded himself only with men he could trust and fought back from a position of strength. Was this why he delayed to play his hand in the stakes for the establishment of the College of Physical Science, in the 1860s, when both Wood and Isaac Lowthian Bell not only saw the necessity for it but were prepared to risk their own reputations by giving evidence before the Durham University Commission of Inquiry?

Equally, the question arises : Why was Armstrong - one of the country's leading industrialists - not called to give evidence before the University of Durham Commission? Was he so disillusioned by the treatment he had received when he had so generously donated his own patents to the nation, that he refused - at least for the foreseeable future - to participate in any further controversial issues? Certainly a letter to his wife seems to support this view. After giving evidence before the Committee on Rifled Ordnance, on a particular occasion, for four hours, he told Lady Armstrong that it was: "a thing I never did before and I trust I shall never do again". (Quoted in McKenzie, p. 73). This Committee, it will be recalled, was meeting at precisely the same time as the University of Durham Commission.

Two items from Bell's evidence seem to give this hypothesis a measure of credence. To the suggestion that perhaps the local industrialists were less than enthusiastic in their support, Bell admitted: 'We all have our own businesses to attend to and I dare say we are very apt to neglect public duty as I think we have done'. (University of Durham Commission Report para 1769). Certainly, this admission is in line with Armstrong's attitude to all the previous schemes for higher scientific education in Newcastle.

When Bell had been questioned further, on this and related matters, Robert Ingham raised the subject of premium apprentices on Tyneside, especially in 'the great engineering works of Armstrong, Stephenson and Hawthorn'. These young men not only paid high fees of around £100 and £300, for the privilege of studying at the works for several years but had to reside in Newcastle during that time. Starting at the age of 16 or 17, their education was practical as well as scientific. (University of Durham Commission Report paras 1838- 1841 passim). Obviously, only parents of considerable means could afford such an outlay. It will be recalled that among the most famous to avail themselves of the scheme at Elswick were the three Rendel brothers, Stuart, George and Hamilton, whose father, James, assisted Armstrong in the early days of his business ventures. The sons, who rose to high managerial positions themselves, became inextricably linked with the advancing fortunes of Tyneside's most prestigious engineering and ordnance works at the height of its fame. Likewise, Percy Westmacott, who became one of the partners in the Elswick Ordnance Works from its inception, had joined the firm in 1848 as a draughtsman and rose to senior management.

Does this evidence throw light on Armstrong's attitude of non-participation in the development of the College of Physical Science in the 1860s? Was he so involved in consolidating and expanding his own business, in building up his management team, and enhancing his own reputation, that he had little time for other matters? Or did he prefer to train up his own supervisors either in the Elswick Works' Mechanics' Institute or through his premium apprentices scheme? By this means he not only ensured the loyalty of his staff, but safeguarded the firm's secrets from industrial espionage. With the establishment of a College of Physical Science and the consequent involvement of firms like Elswick in the practical education of the students, such loyalty and such safeguards would no longer prevail. Unfortunately, lack of hard evidence on this issue can make such a suggestion pure speculation. What, then were the facts?

Not only did Wood and Bell - representing both industry and the Mining Institute - give most noteworthy evidence before the University of Durham Commission, but the Mining Institute continued to press the case, even after Wood's death until, at a meeting under Armstrong's Chairmanship in March 1871, the College of Physical Science was finally established.

At the anniversary meeting of the Mining Institute in August 1862, Nicholas Wood confined his remarks to one subject - that of the Report of the Durham University Commission. From the outset, the meeting supported his argument that the Ordinances issued by the Commission for the future government of the University placed such unacceptable constraints on the Senate that they were 'fatal to the successful establishment of a Mining College'. (<u>Transactions N.E.I.M.E.</u> Vol. XI, 1861-62 p. 219).

Among other matters, Wood was particularly critical of the Commission's proposal which virtually reduced the professors' salaries to £300 a year. This, he argued, was not sufficient remuneration to attract 'the most efficient, most eminent and most competent' staff for the type of college he envisaged. Moreover, he claimed, this would not only reduce the standing of the University, but the lack of confidence thus engendered would limit the number of applicants for other courses. 'It appears to me', he argued, 'that this restriction strikes at the root of the prosperity of a really practical and efficient Mining College'. Recalling that the University authorities themselves were so dissatisfied with the Ordinances that they planned to petition the Government to have them revised, Wood again advanced the cause of higher education for the mining and manufacturing industries. He hoped that not only would the University strengthen their own case by associating themselves with the establishment of a Mining College, but that, equally, the Government would see that this form of higher education was in their own and the country's best interests. (Transactions N.E.I.M.E. Vol. XI, 1861-62 p. 220).

Mr T.E. Forster asked if the offer of the Duke of Northumberland was 'entirely lost sight of?' Wood replied: 'I do not know that it is entirely lost sight of. I fancy if a Mining College was likely to be established at Durham the Duke, on being applied to, would probably aid in the establishment financially. I have this opinion of the Duke that, having made the offer alluded to, he saw the advantage of having a Mining College established and I believe he is still of that opinion'.

Asked if it would be better in Newcastle, Wood admitted that that was a very wide question. 'We attempted (that), but failed for want of funds', he recalled, and doubted very much if enough money could be raised to erect the necessary buildings in Newcastle - estimated between £40,000 and £50,000. 'In Durham', he added, 'they have the buildings and they proposed to provide three professors and also to provide lecture rooms, workshops etc'. Indeed, he did not think it would take a large sum to establish a Mining College within the existing University precincts and, if such were the case, there would be a difference of some £30,000 to £40,000 between establishing the Mining College in Durham and establishing it in Newcastle. (Transactions N.E.I.M.E. Vol. XI, 1861-62 p. 221).

In his own evidence before the Commission, Wood had proposed two grades of students - matriculated and non-matriculated. The former, he told the Mining Institute, would be the same as all other students of the University, and subject to all its rules and regulations. Although the Mining College would be part of the University and subject to the general control of the Senate, it would have managers of its own. However, the non-matriculated students would not be subject to the University's rules and would pay a lower rate of fees. Unfortunately, the Ordinances made no distinction between matriculated and non-matriculated students. Nonetheless, this idea of a two tier system, which would provide higher education for the school leaver and in-service training up to University standard for the experienced employee was, in Wood's opinion, essential to the efficiency of the College as an adjunct to the mining and manufacturing industries. (Transactions N.E.I.M.E. Vol. XI, 1861-62 p. 222).

After further discussion, it was resolved: 'That the committee which was appointed to confer with the University of Durham on the subject of a Mining College be requested to take into their consideration the Ordinances now published by the Government Commission with the view of making such communications on the subject with the authorities of the University as the case may seem to require and that a special meeting of the Council be held on the subject'. (Transactions N.E.I.M.E. Vol. XI, 1861-62 p. 223).

With the death of Nicholas Wood, in 1865, the cause to establish a College of Physical Science lost one of its most ardent supporters at a time when such education stood most in need. Paying tribute to Wood's efforts the succeeding President, T.E. Forster, doubted 'whether the scheme will ever be revived and carried out'. (Transactions N.E.I.M.E. Vol. XV, 1865-66 p. 292).

What hope was there for the future when Armstrong was still too busy reviving his own fortunes; when this 'very desirable project' still met with less support than it deserved from its most likely benefactors and when the future of the University of Durham still lay in the balance? This cloud of uncertainty lay over the proposed college for a whole decade from 1860, unrelieved except for the intermittent spark of light from members of the Mining Institute. In view of that organisation's commendable efforts for technical education, it is appropriate to note that by the mid 1860s they were admitting mechanical as well as mining engineers to their ranks. In this capacity, Armstrong became a member in 1866, by 1868 was Vice President, and was President in 1873.

In these momentous years, Armstrong's involvement with the Mining Institute, in all its aspects - including, presumably, its aspirations for a College of Physical Science - is evident from the frequent laudatory references in the Transactions to his scientific, mining and engineering research. Thus, it would seem reasonable to suppose that he fully supported the promotion of the scheme during the years of his Vice-Presidency of the Mining Institute, yet, with his usual self effacement, he was not to be seen at the forefront of the movement.

Meanwhile, despite the best efforts of the Mining Institute, progress was minimal until, fortunately, outside events were able to settle the issue. The International Exhibition in Paris, in 1867, revealed that the standards of technical achievement in British industry lagged behind those of her major competitors. (Cardwell, p. 111). This fact, and its consequences, finally broke the log jam which had held up the establishment of the College of Physical Science for so long. At last the varying factions were compelled to sink their differences and make common cause. The state of near panic which followed the Paris Exhibition set in train the technical education movement in Britain, whose shock waves were felt throughout the land and not least in North East England. Encouraged by Playfair, the whole subject of technical education was brought before the Government as a matter of urgency. As a result, on the 24th March, 1868, a Parliamentary Select Committee, under the Chairmanship of Bernhard Samuelson, was appointed to consider the matter. Meanwhile Armstrong's arch-rival and future partner, Joseph Whitworth, had taken the lead by offering to endow thirty scholarships at £100 a year for three years. (Cardwell, p. 115). The attainment of these honours later became an integral feature of the Elswick Mechanics' Institute.

The Mining Institute in Newcastle continued its own pioneering work for scientific and technical education as much on a national as on a regional basis. In the Report of 1867-8, the Council noted that they had:

> 'endeavoured to appreciate and utilize the influence for good such a valuable and influential institution is capable of exerting in this district. These efforts, they consider, should be continued and increased in order that England in general and this district in particular should not be behindhand in the scientifc race for greatness now open to competition, not alone as formerly to Englishmen, but to all the nations of the world. England, to maintain her position, will have to look very closely not only to the preservation and economical employment of her vast mineral resources, but she will also have to see that her workmen shall be enabled by a well directed and intelligent course of education to effect the same with skill, safety and economy so that she may not be outrun by other nations possessing less natural advantages'. (Transactions N.E.I.M.E. Vol. XVII, 1867-68 p. vii).

To further this end, the Council met with the North of England

United Coal Trade Association on the subject of Technical Education. Two important events emerged from these deliberations. Three members of the Institute, including Isaac Lowthian Bell, gave evidence before the Select Committee on Scientific Education, chaired by Samuelson. As a direct result, J.C. Buckmaster from the Science and Art Department, came to a meeting at Seaham Harbour on 10th July, 1868, to outline the facilities offered by the Government for the establishment of scientific and technical education amongst the working classes. These ventures, the Council of the Mining Institute hoped, would continue to show more tangible progress before the next yearly meeting took place. (Transactions N.E.I.M.E. Vol. XVII, 1867-68 pp. vii - viii, pp. 65, 77 and 95, passim).

The Transactions of the Mining Institute continued to reiterate that: 'There were no classes, there was no organisation at all commensurate with the great importance of these subjects to the industries in which many present were engaged'. In outlining the Government's policy Buckmaster supported this view. 'From Darlington to Glasgow', he declared, 'there were not three science classes while in the neighbourhood of Manchester there were fifty'. However, he hurled the greatest possible deprecation at Durham University for its intransigence in failing to meet the greatest challenge of the age. 'But so far as the industry of this district is concerned, the Durham University might never have existed. It ought, long since, to have been a great Industrial University for the North of England; it is the feeble shadow of Oxford and Cambridge without its spirit'. (Transactions N.E.I.M.E. Vol. XVII, 1867-68 p. 98).

Observing that there were growing up two classes of men, 'the theoretical who despised mere practical men and practical men who too frequently despised the teachings of theoretical men', Buckmaster asked what provision the Mining Institute had made for the education which would bridge this gap. When it was suggested that no systematic method had really been devised, he outlined the Government's new approach to technical and scientific education and suggested greater collaboration between the parties concerend. Such a challenge, in line with their own long held views, could not be ignored by the Mining Institute. (Transactions N.E.I.M.E. Vol. XVII, 1867-68 pp. 100-101). Although the form of education envisaged was aimed, primarily, at the working man, nonetheless, it opened the way to the establishment of the College of Physical Science. At last the recommendations of the South Shields Committee for 'a fitting institution in the heart of a coalfield', were about to be realised, albeit thirty years on.

When he returned to London, Buckmaster appointed an organiser for Technical Education for the district, and the Mining Institute responded by electing their own Committee on Technical Education. (Transactions N.E.I.M.E. Vol. XVII, 1867-68 p. 113). The Coal Trade immediately replied by 'supplying necessary funds for starting the movement'. (Transactions N.E.I.M.E. Vol. XVIII, 1868-69 p. v). The first report of the Technical Education Committee indicated that 'Mr Rowden (had) offered to come north to carry out a scheme of education in connection with the Government Department of Science and Art'. (Transactions N.E.I.M.E. Vol. XVIII, 1868-69 p. ix). Apparently, W. T. Rowden, 'has had considerable experience at Bristol, and Woolwich, is a successful teacher (and) has had great experience with working men'. (Transactions N.E.I.M.E. Vol. XVIII, 1868-69 p. 7). Armstrong, presumably, had met Rowden at Woolwich and, with his usual shrewdness in appointing men, had obtained the services of this gentleman in the organisation of the science classes at Elswick. So great was Rowden's task that he soon had three assistants to help in his work at Seaham, Murton, Hetton Monkwearmouth and Elswick, while local schoolmasters taught similar classes at Blyth and Seaton Delaval. From the outset, the results seem to have been highly satisfactory. Elswick, with 140 candidates had, by far, the highest number of entries in the examinations - the next nearest being Hetton with eighty nine. The Elswick students obtained 31 first class passes; 48 second class and 32 third class. (Transactions N.E.I.M.E. Vol. XVIII, 1868-69 p. x).

When George Elliot spoke to the General Meeting of the Mining Institute on 7th November, 1868, he used the occasion of his Presidential Address to pay tribute to Armstrong's research into the duration of the British coalfields, and indicated his own ambition to see mining engineering ranking high in the scientific professions with its members more widely appreciated than was often the case. (Transactions N.E.I.M.E. Vol. XVIII, 1868-69 p. 22). Speaking of the North of England Mining Institute, he considered that as the oldest and largest organisation of its kind, it was 'not unbecoming' to take the initiative. To this end, he had already approached the Senate of Durham University and the Institute of Civil Engineers in London with a view to reopening negotiations for a Mining College.

According to Elliot, the authorities of Durham University were 'laudably anxious to fulfil the great purposes for which it was originated and their efforts to promote the cause of scientific education merit the warmest thanks of the mining engineer'. (Transactions N.E.I.M.E. Vol. XVIII, 1868-69 p. 30). This speech is noteworthy on two counts. As Vice President of the Mining Institute Armstrong would be involved in these deliberations. Moreover, this is the clearest indication from Durham

University of a major change in attitudes towards scientific education in general and the promotion of the College of Physical Science in particular. Elliot's complimentary remarks concerning the University indicate that the dire warnings it received from the Government through the University Commission and individuals like Buckmaster had not gone unheeded.

Not only did Elliot observe that the University 'was never in a healthier condition and never had more students at its classes than at this time', but he acknowledged the willing co-operation that now prevailed between the University authorities and the mining industry in devising mutually acceptable courses of study.

> 'The addition now made to its classes, and to the subjects taught, are strong evidence of a renewed youth, and will cause that foundation to render the same invaluable services to the students of the present day, which it has been the glory of our venerable colleges to bestow upon those of the past. At a time when the importance of technical education is generally admitted, when we are agreed to co-operate with the Coal Trade Association in making the advantages offered by the Science and Art Department available for this district, and when private enterprise (is) making endowments on behalf of technical education, there is something peculiarly gratifying in the fact that so valuable a college as that of Durham should (be willing) to promote the objects of this Institution and by placing a portion of its prizes within the reach of our profession, provide an honourable reward for, and supply a valuable stimulant to, the industry of our youth. The provisions made by the University for education in mining seem to me to be of an extremely liberal kind. The student who presents testimonials of good conduct and certificates that he has been engaged in practical work connected with mining for a period of not less than two years may matriculate after keeping three terms of residence in the University. (Thus) he may pursue practical work either as an articled pupil or a colliery viewer and then may go up, and by studying steadily for eight months, fit himself (to) compete for the prizes offered by the University'. (Transactions N.E.I.M.E. Vol. XVIII, 1868-69 p. 30).

Although Elliot admitted that there was still 'much to work out before the connection between the University and our Institute becomes stable and defined' he was confident that the excellent relationships already established between the College of Medicine in Newcastle and Durham University would be a blueprint for further developments. He had no doubt that 'the advantages enjoyed by the students of medicine may be shared by those who adopt mining engineering as their profession and who make proficiency in it the steady business of their lives'. (Transactions N.E.I.M.E. Vol. XVIII, 1868-69 p. 32).

The clearest indication of a breakthrough came when Elliot reported that he had had very satisfactory talks with Durham University. It was now obvious that important lessons had been learned from the past. Both parties were prepared to make concessions and to 'put forward a suggestion rather than developing a plan'. (Transactions N.E.I.M.E. Vol. XVIII, 1868-69 p. 33). This is equally evident from the Minutes of the Senate of Durham University recording that a letter had been received from Mr Elliot indicating his intention to announce, in his inaugural address, proposals for a connection between the Mining Institute and the University. This, Elliot hoped, would establish a more complete system of education in Mining and Engineering than at present existed. Moreover, he asked for guidance regarding the extent to which the University would agree to such an arrangement so that he could make as full a statement as possible in his address. Senate agreed that he should be given details of the existing provisions for education in Mining and Engineering and an assurance that 'the University would gladly co-operate with the Mining Institute in the matter'. (Senate Minutes, University of Durham, 28th September 1868).

The following year, at a general meeting of what was now the North of England Institute of Mining and Mechanical Engineers, the new President, E.F. Boyd, announced that a Committee was to be formed to confer with the University of Durham on the subject of Scientific education, for those destined for the mining and manufacturing professions. (Transactions N.E.I.M.M.E. Vol. XIX, 1869-70 p. 40). In his

Presidential address, he made reference to the decision of the Admiralty to use North Country coal in British naval vessels. This was a direct result of Armstrong's research and his practical suggestions, already noted, which were duly adopted. (Transactions N.E.I.M.M.E. Vol. XIX, 1869-70 p. 52).

After years of wrangling, the establishment of the College of Physical Science came speedily and with the minimum of rancour. By now, society in general, as well as Durham University in particular, had undergone a sea change, and the time was ripe for the establishment of such an institution. As well as being a time of booming prosperity, the second Reform Act had brought the franchise to the artisans and the Trade Unions of the miners had at last been recognised. The enterprise and industrial expertise of men like Armstrong, Palmer, Mitchell, Leslie and Whigham Richardson had made Tyneside renowned as a world leader in building iron ships, in armaments and in marine engineering and design. The rapid expansion of these industries, which demanded a knowledge of applied science, finally convinced local industrialists of the urgency of a College of Physical Science in Newcastle.

By 1871, the Test Acts no longer applied in English Universities; reform in education was an important national issue and Durham University was prepared to participate in that debate. According to the Senate Minutes, the Committee appointed to consider the Endowed Schools Bill had presented their report. In it, they suggested that the Vice President of the Privy Council (W.E. Forster) who was in charge of the Bill, should be fully acquainted with the work of the University which, they averred, entitled it to representation on the proposed Educational Council. To this end, it was agreed that the Warden should write to Mr Forster asking him to receive a deputation on the subject.

(Senate Minutes, University of Durham, 9th March, 1869).

At this stage, every contentious issue which had delayed the establishment of the College of Physical Science was amicably resolved. The time was ripe for progress and the right men, including Armstrong, were in positions where they could wield the greatest influence. Even the thorny question of location between Durham and Newcastle was settled with cordiality. Two significant newcomers to the conflict arrived in 1869. First, Edward Boyd, who was an earnest proponent of scientific education and accepted the advocacy of a base in Newcastle, became President of the Mining Institute. As mining adviser to the Dean and Chapter of Durham he used his influence to advance the claims of Newcastle, despite vested interests within Durham University to extend scientific teaching there. (Whiting, p. 188). In the same year as Boyd's Presidencey, the Rev. William Charles Lake was appointed both Dean of Durham and Warden of the University. A man of wide vision, he maintained that the chief concern of Durham University was the training of clergy and that Newcastle, with its extensive manufacturing, scientific and mining interests, was the rightful venue for a College of Physical Science.

Although, throughout its history, the main aim of the Mining Institute was the furtherance of scientific education applied to that industry, others, including Armstrong, held wider views. Indeed, the question must here be asked: Was the narrow view of applied science the reason for Armstrong's intransigence in supporting the issue, over such an extended period of time? Was he considering the benefits which would accrue to Elswick, before showing his hand? Until a satisfactory answer was forthcoming, was he content to pursue his own scientific career and extend his own business interests and, through the Elswick Mechanics'

Institute, provide the necessary scientific training for his own employees? Whatever the answer, by the late 1860s, he had re-established himself at Elswick and restored his self-esteem in the world of business and as a man of affairs, both locally and nationally. One appointment, which enabled him to influence events at this crucial time, was that of President of the Newcastle Literary and Philosophical Society.

The Society, to which Armstrong and his father had contributed so much from its inception, was, through its extensive library and lecture facilities, virtually a surrogate university, catering more specifically for the ever widening demands of the scientific, business and commercial interests of the area than did Durham University. The Society had long supported the idea of a College or University, offering a wide variety of disciplines, which would reflect the growing needs of the area. Now, they not only had, in Armstrong, a President of acknowledged scientific repute and industrial renown, but, in Robert Spence Watson, a dynamic Secretary who saw the need for swift action and would brook no delay. Dr Thomas Hodgkin, the local historian, supported the scheme, along with members of the College of Medicine and of the Natural History Society and many other influential men in Newcastle, whose civic pride was ready to challenge Durham's claim to supremacy in all but theology. In 1868 Durham University was approached on the subject and within three years the long awaited College of Physical Science had opened in Newcastle.

The Committee of the Mining Institute appointed for this purpose met with Durham University on 2nd August 1870 and found Dean Lake very sympathetic to their views. (Whiting p. 189). Lake had reservations regarding the future of Durham at that time, except as a theological college. He thought that the wisest course would be to establish a science school in Newcastle as expeditiously as possible. So well formulated were his plans that he expressed them in a letter to Dr Tait, his former tutor at Balliol College, Oxford, who was then Archbishop of Canterbury. Lake argued that the proposed college at Newcastle contained the nucleus of a university in the Scottish tradition. 'Of Durham itself', he wrote, 'there is little to be made except as a College for educating clergymen'. (Whiting, p. 189). Although not everyone agreed with him, similar sentiments were expressed by the historian Professor (later Sir John) Seeley to Robert Spence Watson. Moreover, when Archbishop Tait visited Durham, in 1874, and addressed the University in the Galilee Chapel of the Cathedral, he endorsed the view that the chief business of Durham was to train clergy. (Whiting, p. 137). Meanwhile, Lake was adamant. Although many urged him to compromise and establish a College of Science at Durham, his mind was made up. He carried the day with Senate and spearheaded the movement which resulted in an influential meeting being held in Newcastle at which Armstrong presided.

Almost imperceptibly, the tide had been running in favour of Newcastle as the most appropriate venue for some time, despite strong opposition from Durham. A significant move had come when the Literary and Philosophical Society had departed from its usual programme of Monthly Meetings on individual subjects in favour of groups of lectures on specific topics. This innovation was introduced in 1863 when Armstrong, who was President of the Society, had just returned to Newcastle from Woolwich. Although no evidence has been found to substantiate the theory, it could be argued that, given his own scientific propensities, the scheme would have his full approval and support. Among the first to offer their services were the Rev. James Snape, Vice President of the Society, who gave six lectures on 'The Philosophy of Mathematics', Mr Percy Westmacott one of Armstrong's managers at Elswick, and Mr (later Professor) Freire Marreco of Durham University who gave a course of twelve Chemistry lectures during the session 1866-67. (Spence Watson, p. 272).

Another important step was taken when Robert Spence Watson discussed the matter with Professor Seeley who, in December 1867, gave a series of lectures on Milton to the Literary and Philosophical Society and stayed at Spence Watson's home in Gateshead. One evening, during the visit, Seeley asked: 'Why not start a College in Newcastle?' After some further discussion, Spence Watson raised the matter with Durham University. He was invited to lunch with three of their professors, who left him in no doubt that the plan did not impress them, nor were they convinced by the proposals of 'an obscure individual' of the real need for such a college. (Spence Watson, p. 272). Eventually, they agreed that: 'If it is proved to our satisfaction that there is a demand for higher education in Newcastle, even if it be of the kind which must be chiefly given in the evenings, we shall be prepared to take the matter seriously and to bring it before the Senate of the University'. (Spence Watson, p. 272).

Undeterred, Spence Watson read a paper to the Literary and Philosophical Society on 3rd March 1868. Recalling Greenhow's earlier proposals he observed that in Newcastle those who wished to educate the middle classes now had two groups of people to consider - the scientists and the business men 'for whom no provision is made outside the places where they may happen to be immediately engaged'. (R. Spence Watson, 'A plan for making the Society more extensively useful as an educational institution'. Literary and Philosophical Society Tract 0424 - 245, number 2a, p. 12). Recalling that Newcastle was the birth place of so many branches of engineering, Spence Watson paid tribute first to Robert Stephenson whose 'noble bequest (to the Society) had been given in remembrance of the educational use which this institution had been to him and doubtless in the hope that others of his own profession might derive benefit from it'. Equal praise was given to Armstrong, 'our respected President (in whom) we have a constant momento of what we, in Newcastle, owe to our engineers'. (Lecture p. 13). Nonetheless, he agreed that it was essential that their successors should not fail for want of higher education.

After alluding to Owen's College in Manchester, he argued that the Literary and Philosophical Society itself was the ideal location for the proposed new institution. Its lecture room and library were already renowned and there was a large piece of ground behind its premises for the building of classrooms and reading rooms. Conveniently surrounding this ground were several learned societies with similar aims to both the Society and the proposed College. These included the Natural History Society, whose substantial museum was described by Spence Watson as: 'an honour to the North of England, but requiring extension, which would be a fortune to any college in the world'. This was one of many learned societies and institutions which enjoyed Armstrong's patronage and beneficence. The Field Club, with a large and influential membership was described as: 'the most living Society in the district'. Others in the same location included the Society of Art 'which for many years has done good work in and effectual way' (Spence Watson, pp. 274-5) and the Mining Institute, whose outstanding efforts have already been noted. The nearby College of Medicine, with its own extensive facilities and close affinity to Durham University, was seen by many to be the blueprint for the proposed College.

Taking an almost defiant stance, Spence Watson declared that: 'What we wanted was to move the University of Durham bodily to Newcastle and slightly modify its constitution'. (Spence Watson, p. 273).

In order to comply with Durham's proof of the need for such a College, the Society started six courses of experimental evening lectures. Each course consisted of twenty five lectures in a range of subjects including Chemistry, Mathematics, Music, English Language and Literature. The lecturers were all specialists in their field and, again, included Freire Marreco who later became one of the first to combine lecturing at Durham and at the College of Physical Science in Newcastle. Those attending these lectures were given the opportunity for discussion and were to do written work and take examinations. So successful was the scheme that a second session was arranged for 1869-70. Professor Seeley, who followed the experiment with keen interest, remarked, prophetically: 'Newcastle is, in fact, constructing a University'. (Spence Watson, p. 279).

Alas, as Middlebrook observed, in his own lecture to the Literary and Philosophical Society, in 1971, commemorating the centenary of the founding of the College of Physical Science: 'Spence Watson and the Society had spent their ammunition and could do little more'. (S. Middlebrook, The Literary and Philosophical Society as an Educational Pioneer, 1974, p. 17). In his view: 'The actual foundation of the College of Physical Science in October 1871 was the outcome of protracted negotiations between Nicholas Wood and E.F. Boyd representing the Mining Institute and the enlightened, sympathetic Dean Lake, Warden of Durham University'. (Middlebrook, 1974, p. 17). Given the evidence, this, on balance, is a very fair assessment.

Meanwhile, what rôle had Armstrong still to play?

With his characteristic sense of timing, he showed his hand at the Social Science Congress held in Newcastle in September 1870, in a keynote speech, entitled Economy and Trade. Noting that "industry and trade go hand in hand", he argued that "both require for their vigorous growth an atmosphere of freedom" and welcomed the fact that in England "protective legislation on commerce is now, happily, on the wane". (W.G. Armstrong, "Economy and Trade", Transactions of the National Association for the Promotion of Social Science, Newcastle upon Tyne Meeting, 1870, published 1871, p. 77). As one of the country's leading industrialists, and given the remit of his subject, he, naturally, spoke of the wider issues of economy and trade. These included labour relations; the role of the Trade Unions and the Patent Laws. Nonetheless, he made some perceptive observations on the education of the working classes which, arguably, have a bearing on his intransigent attitude towards the establishment of the College of Physical Science. "Struggle for superiority", he observed, "is the mainspring of progress. It is an instinct deeply rooted in our nature (which) shows itself in the homage which we render to success even in matters of little moment". (Armstrong, Transactions N.A.P.S.S. p. 80). He advised the Trade Unions to pursue a more rational policy by encouraging their members to organise manufacturing societies on a co-operative basis, instead of repressing their latent ability and energy. The practice of frugal habits, he maintained, would quickly raise the capital necessary for investment in the co-operative trade. He further argued that: "If a yearly sum, equal to that which is now worse than wasted on intemperance, were set aside to create capital for this purpose, ample funds would speedily be raised to commence (such) undertakings". (Armstrong, Transactions N.A.P.S.S. p.80).

Armstrong's words are noteworthy, not only in the immediate context, but because they explain his attitude towards the Engineers' Strike which took place only a few months later. It brought the whole of Tyneside to a standstill and had extremely dire consequences not only for Elswick, but for Armstrong's reputation as an employer. Nonetheless, he spoke of labour with great respect, describing it as "the foundation of value", and arguing that even "machines for saving labour are themselves the offspring of labour, and capital is nothing more than an accumulation of the unused products of labour". (Armstrong, Transactions N.A.P.S.S. p. 78).

In his view, the greatest impediment to social and industrial progress was not so much the raising of capital as raising the standard of education, especially among the working classes. His view of the subject was not confined to the classroom, but to the 'whole man'. To this end, he sought an education which would fit them to take part in the type of joint enterprises which he had outlined, and hoped that "the day will come when, with better teaching and more frugal habits, the working classes will be enabled to participate in the employment of capital as well as in the receipt of wages". (Armstrong, Transactions N.A.P.S.S. p. 80).

His true philosophy - for education as much as industry - is displayed in full measure in this speech. In his view, the operation of market forces, rather than State assistance would enable the worthy and the enterprising to reach their goal. Again the question must be asked: Is this why he stayed his hand when all about him were crying out for the establishment of the College of Physical Science? Or were weightier concerns at Elswick of more immediate importance to him? Whatever the answer, let his own words speak for themselves:

> "Under the best constitution of society it will only be those who begin by practising frugality, and who possess industry, perseverance, and ability, that will rise above the general level, and make for themselves a position superior to that of the multitude. The working population of this country abounds with men adapted by nature to rise above their fellows, but who are kept down by want of education and the repressive influences which surround them. Men of this stamp, in whatever class they may be found, represent the nerves of the nation, and the more their talents and energies can be brought into action, the better it will be for the wealth and greatness of the land which claims them". (Armstrong, Transactions N.A.P.S.S. p. 81).

This was the bedrock of Armstrong's views on education, from which he never wavered. It was not educational opportunity but self motivation that distinguished success from failure. He, the untrained engineer, had risen to the top, why could not they?

In summarising, he took the attitude which, although popular in his own time, would find equal favour in some influential quarters today. He argued that: "The greatest good to the greatest number will only be maintained by leaving the social world as much as possible to the governance of natural laws". (Armstrong, Transactions N.A.P.S.S. p. 83).

The tenor of his speech, stressing as it did, the social rather than the industrial problems of the day, serves to emphasise the breadth of Armstrong's interests and influence. Already at ease among lawyers and engineers, his incisive mind was equally in tune with the concerns of the educator and the social scientist. Was it his breadth of intellect that distinguished him from educators of his own, or any other, time?

The President of the Conference was Algernon George Percy, sixth Duke of Northumberland, whose early education, as Lord Lovaine, has already been compared with that of Armstrong. These two contemporaries continued, for the next two decades, to wield considerable influence in the social, landed and industrial concerns of the region. On the occasion in question, the Duke, Playfair, Sopwith and Spence Watson spoke on the need for educational reform. Nonetheless, in the present context, the speech made by the Dean of Durham, immediately following that of Armstrong, is the most noteworthy.

From the outset, Lake endorsed Armstrong's 'wise and generous words in favour of hundreds of our workmen who have within them the power to rise if you show them the way and whose wasted talents have been so much loss to their country'. (The Very Rev. Dean of Durham, "Scientific Education of Miners", Transactions of the National Association for the Promotion of Social Science, Newcastle upon Tyne Meeting, 1870, p. 337). Lake set the parameters of his discourse under three main headings:

1. What is the importance, especially to practical men, of an education in physical science?
2. Is this education sufficiently given at present to our miners and engineers?
3. By what means can we best advance it?

He acknowledged that, although the ability of our great engineers and miners remained undisputed, he wished that they could find the education necessary for their advancement nearer home. At present, they had to study in London, Edinburgh or even Europe. He argued that the desired course in scientific subjects should be locally based and should include mathematics, chemistry, hydraulics, hydrostatics, pneumatics and practical chemistry or geology. Moreover, he considered that such scientific knowledge would be equally useful in what were, then, the emerging sciences of magnetism, electricity and telegraphy. In this region which could boast of some of the greatest works and some of the greatest wealth in the Kingdom, and which had the intelligence to match it, why, he asked, was there not an equally great College of Mining and

Engineering? In continuing his argument for better education, he used Lowthian Bell's theory that there were two extremes: 'the highly educated or those not educated at all', and he suggested that 'we stand very much in the North of the means of education for those in the intermediate degree'. (Lake, Transactions N.A.P.S.S. pp. 338-40).

He observed that although inspectors were employed in mines and foremen in manufactories, the education of these men was woefully lacking. Despite the weight of responsibility which they carried, most of them had risen from the ranks and had been entirely self educated. How far, he wondered, would such a situation be allowed to prevail among other professions? Already, he remarked, the miners of Durham and Northumberland had taken the laudable initiative of presenting a petition to the House of Commons, in 1865. In it they requested that all their agents, overmen and managers should undergo a scientific examination and that a Government certificate of competency should be awarded before anyone was allowed to take a supervisory position in a mine.

In advancing his argument, Lake reiterated that while the education of the highest classes left much to be desired, that of those entrusted with mine safety was non-existent. He cited the case, so beloved by the exponents of 'laissez faire', that engineers like Brindley and George Stephenson were entirely self educated yet had not been impeded in their upward mobility. While he acknowledged the validity of such widely held beliefs, he condemned them for their obsolescence. In words evocative of Wood's own arguments, he refuted the idea that 'because now and then we get a genius, in spite of his want of education, it is therefore better to educate no one'. He continued: 'It is not a question of producing an occasional genius like Stephenson, it is a question whether the mass of our young men of talent shall have their talent cultivated or shall be left half ignorant of their work and therefore dangerous to others'. (Lake, Transactions N.A.P.S.S. pp. 341-2). What, he wondered, is the most appropriate kind of education and where is it to be given?

He welcomed the new national system of elementary education for the humblest class of worker, although he suggested that the curriculum should vary according to the needs of the boys' future employment. The cleverer boys, he argued, should be able to advance from elementary to higher education. In this regard, he recalled the views expressed over the years by members of the Mining Institute, including Wood, Elliot and Bell, that 'the North of England ought to possess a course of systematic instruction in physical science'. (Lake, Transactions N.A.P.S.S. p. 343). He urged that no one should rest until such an institution was established in the area which would compare favourably with those in other parts of the country. By this he warned that he did not mean 'a mere system of popular science lectures given in the evenings when the mind is all but half itself'. While he conceded that these were good in themselves, 'it is absurd to call them education'. He insisted that it was essential to have an institution which would specialise in scientific education, and reminded his audience that the foundation of such a college, although a 'great work' should not be 'a very difficult one'. Too much time had already been wasted in argument, he maintained, so he recommended that the leading men in the district should petition the Royal Commission, then in session, to consider the establishment of such an institution in Newcastle.

He recalled the endeavours of the University of Durham to found such an institution, either for itself or in Newcastle, and expressed the conviction that, given the close proximity of the two places, they could work together to achieve the desired end. He was confident that the University, in conjunction with established institutions like the Mining Institute, could set a high standard of lectures in appropriate subjects.

Finally, he admitted that, although in providing scientific education, Newcastle compared very unfavourably with Manchester, Liverpool and Leeds, he was convinced that, given the right start and commitment, the balance would soon be redressed. (Lake, Transactions N.A.P.S.S. p. 344).

Lake made this speech only a year after being appointed Dean of Durham and Warden of Durham University. This appointment was, according to Whiting, 'more absolute than any authority in this or any other University'. (Whiting, p., 137). When the Deanery became vacant, in 1869, The Times, in a leading article, had highlighted the failure of Durham University to supply the educational needs of the North, despite its considerable resources. The paper requested the Prime Minister to appoint as Warden someone who was not only a powerful and vigorous educational expert, but one who might take the lead in reforming and reorganising the University and bring it more into line with the requirements of the time. As a result, the post was given to the Rev. William Charles Lake, Rector of Huntspill in Somersetshire and Prebendary of Wells. (K. Lake, (Ed.) Memorials of William Charles Lake, Dean of Durham, 1869 - 1874, 1901, p. 118). This appointment proved to be an inspired choice for the North in general and the College of Physical Science in particular.

Not only had Lake been a Tutor at Balliol College, Oxford, and served on several Royal Commissions on education, but he was a man of vision, energy and enthusiasm who could identify the essentials of a problem and work through the task to its completion. For the next twenty five years, according to his widow, he regarded the Deanery and Wardenship at Durham as his life's work for which his earlier life was but a prelude. (K. Lake, p. 113). In the present context, his involvement with the College of Physical Science and his encouragement of Armstrong and other industrialists to share his commitment, are the most noteworthy parts of that work.

He described Durham University as being 'adequately but not richly endowed, (whose) earliest days gave great promise of success'. Nonetheless, despite the academic distinction of the staff, the University had sunk into almost absolute decay and the numbers, by the time he arrived, had dwindled to about fifty. (K. Lake, pp. 114-5). Therefore, he realised that before him lay two courses which had reasonable chances of success. The first was to create the College of Physical Science at Newcastle and the second was to ensure that Durham University continued as a centre of excellence for the teaching of theology. In his opinion, there was no alternative. Indeed, the only future for Durham University, as he saw it, lay in the success of its two great schools; that of theology at Durham and that of science at Newcastle. As a University for classics and literature, he argued, Durham would always be overshadowed by Oxford and Cambridge. Nonetheless, he claimed that the case for theology at Durham rested on the great need for such teaching in the Anglican Church. Equally, and with commendable foresight, he saw that the other real prospect for success lay in the College of Physical Science at Newcastle. Nor was his trust misplaced. Within ten years of its foundation, he was able to write that the College 'has achieved a success which, considering the smallness of its endowment, is most remarkable. It now has the character of a University and in point of extent of work and of the numbers of its professors and teachers, it far exceeds the Durham portion of the University'. (K. Lake, pp. 115-6).

The Dean not only saw that any attempt to compete with the older universities on their own terms was a recipe for disaster, but, unlike some of his predecessors, he realised that success at Durham could be achieved only with the goodwill and active co-operation of the leaders of Newcastle and its district. Almost thirty years had passed since the South Shields Committee had met with the Senate of Durham University to consider the establishment of 'a fitting institution in the heart of a coalfield', yet no real progress had been made. How was Durham's pride and Newcastle's prejudice eventually broken and what was the nature of Armstrong's response?

When Lake learned that there was no organised provision in the North for practical scientific training, he felt that this was the primary objective to which the University should devote its surplus funds and energies. First, he persuaded the Senate to agree to his plans and then laid them before an influential meeting in Newcastle.

It was said of Lake that 'while he could conceive a bold project and see the right end at which to aim, he had no mind for details'. (K. Lake, p. 120). To some extent, his critics claimed, this led him to underestimate the true extent of the problem. Nonetheless, like Armstrong, he had the insight to assess another man's potential capabilities and, after placing him in the right position for his talents, he left him to solve the problem on his own.

The practical side of his nature is evident in his careful recruitment of the leading business men in the region during the foundation of the College of Physical Science. A remarkable exercise in what would now be termed 'public relations' is seen in the use he made of Mr Joseph

Cowen, the influential proprietor of the Newcastle Daily Chronicle, who, subsequently, used that medium to promote the best interests of the College. Nonetheless, important though Lake considered the power of the press to be, he looked back with even greater satisfaction to the time when he enlisted the active support of such leading industrialists as Armstrong and Lowthian Bell. According to Mrs Lake, these men, by their zealous support of the College, did much to make it an essential part of the region's greatness. (K. Lake, p. 121).

Indeed, Lake's powers of persuasion must have been truly remarkable because both Armstrong and Bell were too shrewd to have been tempted by some spurious scheme which was not industrially and economically viable. It could be argued that Bell was already a member of the Committee of the Mining Institute negotiating with Durham University for the promotion of such a scheme. Nonetheless, for Lake to have involved Armstrong - the most famous and influential industrialist in the region, if not the country - was, in itself, a noteworthy event. Lake's idea must have had every indication of feasibility, and the question must be asked: 'What was in it for Armstrong?', when, after so many years of hovering, he was at last persuaded to support the establishment of the College of Physical Science in Newcastle.

Did he see, at last, that, despite the excellence of his Mechanics' Institute and of his premium apprenticeship scheme at Elswick, the advancement of technology was too swift for the voluntary principle to cope effectively? Only by combining resources - human and material as well as theoretical and practical - could he and the other British industrialists match their European rivals.

When the Mining Institute appointed a committee to confer with the University of Durham on the promotion of a College of Physical Science, they apparently met on 2nd August, 1870. (Whiting p. 189). No press reports have been traced on the event, other than a passing reference by Boyd that a meeting took place in Bell's home at Washington, County Durham. (Newcastle Daily Chronicle 13th March, 1871). Dean Lake was entirely sympathetic and used his position to raise the urgency of the case with the University Senate. Events thereafter moved swiftly to their conclusion.

The members of the Mining Institute then convened a meeting on 11th March, 1871. Held in the Lecture Theatre of the Literary and Philosophical Society, its remit was: 'To consider if, by the united action of the University of Durham with the scientific societies and manufacturers and gentlemen of the district, some provision could be made for the establishment of classes for the teaching of physical science'. (Newcastle Daily Chronicle 13th March, 1871). Sir William Armstrong was, by unanimous consent, called upon to preside. The importance of the occasion is further reflected in the number of influential people present. Not only was Durham University represented, but a strong presence of Tyneside's civic, industrial and scientific leaders also attended. Further indication of the importance of the occasion is seen, not only by the presence of Joseph Cowen himself, but by the full press coverage which followed.

The Chairman invited Mr Bell to outline the purpose of the meeting. He indicated that the industrial expansion of the area was now of such magnitude that the manufacturers themselves realised the urgency of improving the facilities for the study of the physical sciences, especially for those aspiring to managerial positions in the mining, manufacturing and chemical industries. Hitherto, Bell recalled, much had been achieved by the so called 'rule of thumb' method. While he did not undervalue its importance, he was confident that his audience would agree that the time had now come when it was no longer tenable and that the establishment of a College of Physical Science was of the utmost urgency. The vital question was: 'Where should it be located'? He recalled his evidence before the University of Durham Commission when he had strongly argued the case for Newcastle. Not only was it the centre of a large manufacturing region and possessed railway facilities which few towns could match, but it already had scientific institutions whose facilities, in the short term, could form the basis of such a college without any further adaptation. A geological museum and other appropriate facilities were readily to hand. The lecture theatre in which they were meeting, presented by Armstrong, was 'second to none in the Kingdom'. Now it would, through the generosity of the Chairman, be placed at the disposal of the College. Thus, he argued, if the men of the district applied their usual energy to this project, a College of Physical Science in Newcastle would soon be a reality.

Despite the proximity of Durham, he continued, it had not been too successful either in science and literature or in the number of its students. However, he understood that there were funds available in the University which, if not reserved for some other use, might be used for the purpose now proposed. He was of the opinion that not only were some members of Durham University sympathetic to the College being located in Newcastle but they felt that if the funds in question were used for its foundation they would render valuable service to the North of England.

He considered that, initially, the institution should be placed on a modest footing. It would be foolish in the extreme, he argued, to mount an expensive scheme which could fail and involve great loss and disappointment. After detailing the estimated cost of such a project, he indicated that, because several firm promises had already been received, more money would be forthcoming as soon as the project became a reality. While he did not know the extent of the assistance from Durham, he considered that it would be a disgrace if the men of Newcastle could not, themselves, raise the necessary funds, without any outside assistance, whatsoever.

Edward Boyd, President of the Mining Institute, supported Bell's views, especially regarding the location in Newcastle. He was mindful of the difficulties experienced by young men destined for managerial positions in the mining industry of having to go to Durham on a full time basis. The only alternative, he averred, was to found a College in Newcastle with three professorships - chemistry, physics and natural history. He recalled that when Bell had invited members of the Mining Industry to meet with the Dean and other representatives from the University, at his home in Washington, they were told that, although funds were available for the purpose envisaged by the meeting, under the Act of Parliament, the money could only be used in connection with the University and not to found an independent college. He knew he had the support of the Dean and some others, and was confident that, despite the difficulties, they could come to some arrangement with the University authorities. Tó this end, Boyd had asked the Dean to state his views on paper, so that the meeting would know the full extent of he case.

He then read the Dean's letter, which affirmed that he, Lake, had always favoured a Newcastle based institution. Lake estimated that the smallest sum required to provide the necessary buildings, staff and apparatus would be about £2,000. In order to reduce the expenditure, he was prepared to place before Senate his proposal that, since a minimum of three professors would be required, these should be Durham based men who would spend half their time in Newcastle. By this means the Newcastle institution would not only save expense but would have the advantage, from the outset, of men with proven university experience, as well as the practical expertise required by the Newcastle industrialists. After giving precise details of the expenses involved, he observed: 'I have gone on the supposition that this will be in the nature of a working college and not of supplying popular lectures such as those usually given in the evenings'. (Newcastle Daily Chronicle 13th March, 1871). Although he stipulated that in order to apply Durham funds to such a project it must be connected to the University, nonetheless, he added that such a bond need only be slight and he hoped that the management would be based in Newcastle.

Both the speeches and the Dean's letter roused considerable interest in the meeting, which was reflected in the liveliness and length of the discussion which followed. Among those who spoke was Mr Joseph Cowen who expessed the general feeling of the meeting when he reiterated the view that if a small institution were founded on a sound basis, students would flock to it and it would soon become prosperous.

Mindful that a College of Medicine had already been established in Newcastle, with close connections with Durham University, the comments of some its senior staff who attended the meeting do not seem inappropriate. Dr Embleton recalled that the College of Medicine had, originally, been founded as an independent institution. On the whole, despite some differences of opinion with its own staff and with Durham University the insitution had progressed successfully, over the years. Some 300 students had been educated there, and he believed that their experience could be a useful pattern for the proposed institution to follow in the first instance. Although they had found the benefits of working independently, nonetheless, it was desirable to be associated with Durham University, which could confer degrees upon the students.

Dr Charlton endorsed these views and indicated that the present Dean expected the association of affiliated colleges with the university to be as close as possible.

After several other useful contributions had been made to the discussion, the Chairman summarised the views of the meeting. Armstrong said that, in his view, the meeting concurred with the sentiments expressed in the Dean's letter, except with regard to the time sharing of the professors between Durham and Newcastle. He noted that the need was strongly felt for a modest, but sound beginning to be made. In that case, he proposed that their best plan should be to limit the number of subjects offered, so as to minimise the expenditure on professors' salaries. Nonetheless, he felt that the immediate question was: 'What answer should be returned to the Dean's communication'? He considered that perhaps the most proper course would be for Mr Bell and Mr Boyd to meet with the Dean to convey the feeling of the meeting and to invite him to reconsider the subject of the offer of aid from the University in a less objectionable form. He thought that the probable outcome would be that the Dean would so far modify his proposition as to meet the requirements of the meeting yet, at the same time, be prepared to offer really substantial aid. He, personally, supported the case for the association of the College with the University, yet, at the same time, he shared the view that there should be no divided services. Then, with that meticulous sense of timing which characterised all his dealings, Armstrong delivered his coup de grâce. He maintained that if the University would agree to transfer the scientific branch of their education wholly to Newcastle, so that the professors could exercise their duties exclusively there, and if, as Dr Embleton had suggested, a regular dialogue was establsihed between the two institutions, a very useful association would result.

The Mayor considered Sir William's ideas to be very sound, and the meeting closed with a vote of thanks to the Chairman. (Newcastle Daily Chronicle 13th March, 1871).

The instigators of the College now moved with commendable alacrity in order to realise their objective. Exactly a fortnight after he had presided at the previous meeting, Armstrong was called upon to perform the same office at a well attended public meeting in the same place, on 25th March 1871. The meeting was convened 'to further consider the establishment of classes in Newcastle in connection with the University of Durham for teaching Physical Science'. (Newcastle Daily Chronicle 27th March, 1871). The Editorial of the Newcastle Daily Chronicle gave abundant praise. It spoke of 'a red letter day in the calendar of social and scientific progress for the North of England (when the) hopes and wishes of forty years found expression in those branches of science which bear direct relation to the staple industries of the district'. (Newcastle Daily Chronicle 27th March, 1871).

Armstrong, in his opening address, noted that the Dean of Durham had considered the proposals of the previous meeting and had prepared a draft plan. This obviated the idea of sharing the professors' time between Durham and Newcastle, and made an increased monetary offer. Although the latter required an equally generous response from Newcastle, Armstrong was confident that, "if they rose to the occasion, they would succeed in establishing in Newcastle a School of Science worthy of the great wealth, intelligence and importance of the district".

(Newcastle Daily Chronicle 27th March, 1871). In actual fact, the University had promised an annual sum of £1,250, obtained from the depression of some of its fellowships, if Newcastle would guarantee a similar amount. (Whiting, p. 189).

The Dean, who must have worked with excessive diligence to have won over the Senate to his views, suggested that the minimum requirements for a viable institution would be the appointment of four professors. The course, he argued, should be of two years' duration and should end with some prestigious award of University standing, perhaps an Associate in Physical Science. He made particular reference to the fact that he had found the University 'to be cordially disposed towards Newcastle and the North of England generally'. (Newcastle Daily Chronicle 27th March, 1871). Indeed he praised his colleagues for the assiduous manner in which, for the past year, they had considered the best way of improving the scientific training available to the local industries. Nonetheless, Lake felt that there were many arguments in favour of Durham. In the life of a University, young men were enabled to mix with people from different social classes and cultures. Indeed, the opportunity for University study was one which should not be dispensed with lightly. Nevertheless, he did appreciate that, from a practical point of view, the young men in question did not have the means to leave their work and go to Durham, even for one year. Thus, the only feasible location was Newcastle.

Despite the goodwill of Durham, the scheme was still more 'a matter of hope than experience'. Thus, the University hesitated to guarantee unlimited funds to a project which might fail. They had decided to err on the side of caution when they agreed to assist the institution for six years, with the proviso that if successful, the College was guaranteed their future support. Nonetheless, their offer was dependent upon Newcastle matching their generosity in equal measure. Given the prosperity of the region, they maintained, this should not be difficult. After six years, they claimed, the College should be in a sound financial position especially as the course fees from the students would increase their revenue. The Dean continued to outline, in great detail, the recommendations of the University, whereupon he advised the influential men of the district not to let the subject drop but to advance the scheme which was not only in their own best interests but which would bring considerable benefit to their workforce. (Newcastle Daily Chronicle 27th March, 1871).

The Mayor proposed and Bell seconded the motion that a College of Physical Science should be established in Newcastle. Evidence of the future direction of the College can be seen in the hope expressed by Bell that, in addition to the mining and engineering industries, the agricultural interests would also lend their support. He happily reported that he had had an interview with the Commissioner to the Duke of Northumberland who indicated that His Grace's feelings towards the establishment of the College were 'not inferior to those which were entertained by his predecessor Duke Algernon'. Although Bell admitted that he could not say how the Duke's interest would be manifest, he was at liberty to promise that 'he would be willing to lend a helping hand'. (Newcastle Daily Chronicle 27th March, 1871). Bell then expressed the view that the meeting was under a considerable obligation to the Dean for his efforts and Newcastle could do no less than accept the proposals and make them viable. After prolonged discussion in which the interests of both Newcastle and the University were fully expressed, the resolution of the meeting was passed unanimously.

Bell thereupon proposed that a subscription list should be opened immediately. He indicated that the Chairman (Armstrong) had already offered to head the list by donating £100 a year for the five or six years of the experiment's duration. Bell, for his part, then offered £50 a year for the same period. By the end of the meeting, more than £3,000 - equivalent to half the sum required to be guaranteed - was raised by those attending the meeting, alone.

Before the meeting closed, an executive committee was appointed. The relevant names included Armstrong, the Dean of Durham, Bell, Boyd, (President of the Mining Institute), Dr Embleton, (representing the College of Medicine), Albany Hancock (representing the Natural History Society), Thomas Hodgkin, R. Spence Watson, (representing the Literary and Philosphical Society) and Lindsay Wood, whose father, Nicholas, had done so much to promote the scheme. (Newcastle Daily Chronicle 27th March, 1871).

The first cohort of 50 students arrived in October 1871 at a time when it was customary for newly appointed professors to give an inaugural lecture. Thus, on successive days, from 9th October to 12th October 1871, Professors A.S. Herschel, (Experimental Physics), Steadman Aldis (Mathematics), David Page (Geology) and A.F. Marreco (Chemistry) addressed a large audience of students and distinguished visitors in the lecture theatre of the Literary and Philosophical Society. (Newcastle Daily Chronicle 10th October - 13th October, 1871).

The official inauguration of the College took place on 24th October 1871. According to a contemporary account, 'the proposals met with general approval and the undertaking was at once attended with a peculiarly large measure of success. The most liberal contributions flowed in from all sources; the financial prospects were very promising and the future prosperity of he College was looked upon as beyond question'. (Fordyce, Vol. IV, 1867 - 75, p. 167). The inaugural ceremony, at which Armstrong again presided, was held, like the previous meetings, in the lecture theatre of the Literary and Philosophical Society. The Dean of Durham gave the principal address, and other distinguished guests included the Duke of Northumberland, Earl Grey and representatives of the civic, spiritual, academic and industrial interests of the area. (Fordyce, Vol. IV, 1867 - 75, p. 167).

The local press gave full coverage to the speeches. In a leading article, the Editor of the Newcastle Daily Chronicle gave a useful and objective summary indicating that:

> 'frequent attempts have been made to organise a school of science in Newcastle that should bear the same relation to the Durham Alma Mater which the affiliated colleges in all parts of the country bear to the University of London. But all such attempts fell through; and it seems probable that they failed, in no slight degree, because they were not originated by the University itself, and were not even shaped so as to ensure its full sympathy by entrusting it with a fair share of responsibility and supervision'. (Newcastle Daily Chronicle 25th October, 1871).

Armstrong, as Chairman, introduced the occasion by intimating that:

> "The formation of a Physical Science College in Newcastle has long been a cherished object with many friends of science in this district, but that object proved unattainable until the University of Durham gratified its friends and appeased its enemies by coming forward in a new sphere of usefulness, and lending the aid which was necessary to lead to success. This enlightened proceeding, so much in harmony with the spirit of the age, took place under the auspices, chiefly of the Dean of Durham, who has not only exercised his influence in favour of this undertaking but who has taken an active and laborious part in realising the project. He has, therefore, been selected as the fittest person to deliver the inaugural address on this occasion and he will now proceed to discharge the task which he has so kindly undertaken". (Newcastle Daily Chronicle 25th October, 1871).

The Dean's lengthy address, which was rapturously received, outlined the difficulties in establishing the College, despite the urgent need for such provision in the region. He spoke of Armstrong as having 'the reputation of a really scientific discoverer (who) would be listened to on every question in which he was interested'. While emphasising the importance of science, the Dean reminded his audience of the need to retain classical and literary studies, and of admitting women to their classes. He further hoped to see 'the early foundation of a Professorship of English History and of Political Economy', but concluded that: 'it rests with the people of Newcastle to determine whether there shall be established here a more complete form of education than we can offer today'. (Newcastle Daily Chronicle 25th October, 1871).

After other speakers, representing local civic and industrial interests, had offered their congratulations and support, a luncheon was held in the Central Exchange. Here Armstrong again presided and Earl Grey proposed 'success to the College of Physical Science, coupled with the name of Sir William Armstrong'. Grey observed that:

'The name of Sir William Armstrong had a European, or rather a world-wide celebrity for the success with which he had applied physical science to useful productions - not only in regard to those fearful instruments of destruction with which his name was so closely associated, but, what was of far more importance, to a variety of machinery and contrivances of the utmost value for supplying the wants of mankind. The example and success of Sir William Armstrong was the strongest encouragement that could be given to those who would attend the college which had now been founded and therefore it was most proper that his name should be coupled with the toast'. (Newcastle Daily Chronicle 25th October, 1871).

In replying to the toast, Armstrong admitted that he was:

"but one of a large committee who had devoted its labours to the promotion of the undertaking, and whatever thanks were due in respect of those labours, were due to the committee jointly, and not to himself individually".

He then expressed the hope that:

"the example which had been shown in Newcastle in regard to the establishment of that college would be rapidly followed in all other important towns in the country, for (he was) satisfied that it was only by scattering local colleges over the whole land that they could hope to effect that widespread diffusion of scientific knowledge which was so essential to the advancement of the nation in a moral as well as an intellectual point of view. That object would not be effected by great national scientific colleges, but only by bringing scientific instruction to the doors of the people. They must enable them to have it at home and not allow them to be any longer deterred from seeking it by the great expense and inconvenience of travelling to distant places. It was surprising how little had yet been done in the way of spreading scientific knowledge amongst the people of this country. It was very different on the Continent. Had scientific instruction not been confined, as it had been, to a few persons, we should have had a vastly greater amount of practical and beneficial results arising from the application of science than we had actually experienced. The value of scientific education was held in far higher estimation on the Continent than in England. Its value had been fully recognised by all those nations who were our rivals in industry, and it was clear that the greater diffusion of scientific knowledge amongst those nations had been the principal cause of the more rapid progress which had been observable in their industries than in our own. We were far more ahead of our rivals 20 years ago than we were at the present day and unless we awakened to the necessity of improving our condition by the promulgation of science, we might expect to be rapidly overtaken. Our rivals were already close upon our heels - closer than was generally admitted in this country, and it ill behoved us to slumber in fancied security. (He hoped that) the college which had just been inaugurated might tend to avert that danger, not only by its direct local effect, but by leading to the establishment of several similar institutions in other parts of the country". (Newcastle Daily Chronicle 25th October, 1871).

In this speech, Armstrong at last showed his unequivocal support of the College of Physical Science. Not like Dean Lake, who preferred a liberal arts college, but as an industrialist who needed a workforce ready to adapt to tomorrow's technology. Herein lies the answer to the two recurring questions: 'Why did he hesitate so long?' and 'What did Armstrong stand to gain?'

Now he realised that, with their structured system of scientific education, at the higher levels, his foreign rivals were not only competing but were outpacing him. Thus, there was only one option open to him - to beat them at their own game through the establishment of a College of Physical Science in Newcastle. Although the Elswick Mechanics' Institute and his premium apprentice scheme would continue to serve their purpose, the day of the professional engineer - equal in every respect to other professions - had arrived. Armstrong, with his characteristic sense of timing, knew this and acted accordingly.

Armstrong the lawyer was convinced by the evidence; Armstrong the scientist and engineer was inspired by the prospect of a centre of scientific excellence in close proximity to Elswick, while Armstrong the captain of industry had always been aware of the financial implications of a highly educated workforce.

Thus, thirty years after the South Shields Committee had met with the Senate of Durham University to propose such an institution, it was, at last, a reality. Although not in the location that they had envisaged, nonetheless, it was still 'a fitting institution in the heart of a coalfield'; one to which Armstrong had, at last, given his unequivocal support and one on whose Council he served as a life member.

Despite the generosity of the inaugural funds, adequate building was impossible. Accommodation was provided in the 'cellars and attics' of the Mining Institute, while the facilities of the Literary and Philosophical Society, of the College of Medicine and of the Natural History Society were placed at the disposal of the burgeoning College. (Fowler, p. 206-7). When a new site was chosen in Barras Bridge for the, then, Durham College of Science, Armstrong laid the foundation stone of the College which was to bear his name and which, in the present University of Newcastle upon Tyne, is still known as the Armstrong Building.

CHAPTER XI.

ARMSTRONG'S ELSWICK SCHOOLS, PART I.

BOYS' DEPARTMENT.

When Armstrong addressed the Social Science Congress in Newcastle in 1870, on the subject of working class education, his words were not merely the theoretical musings of a leading industrialist. He had already tried to relate theory to practice when he provided a new building and improved facilities at the Elswick Mechanics' Institute in 1863 and, in 1866, 'erected, in close proximity to the Institute, handsome and commodious schools for the children of the men employed at the Works'. (Newcastle Daily Chronicle 10th April, 1866).

The public inauguration of the Elswick Works' Schools, which was held in the large assembly room of the Institute, drew a large audience and consisted of addresses and a concert. As the papers noted: 'Additional éclat was given to the occasion because of the announcement that Sir William Armstrong would occupy the chair and deliver the inaugural address'. (Newcastle Daily Chronicle 10th April, 1866).

At the outset, Armstrong indicated that, although the Schools were being provided for the children of the Elswick employees, he trusted that they would bring great benefit to the neighbourhood as a whole.

As always, Armstrong's arguments were convincing, straight forward and relevant, both to the subject in hand and to his audience. On this occasion, he revealed his views on a curriculum appropriate to the needs of the children, not only in their present social station, but to whatever higher position they might aspire in the future.

First, he indicated that he knew "of nothing more urgent for the public welfare than the adequate means of educating the mass of the people". To this end, he argued that children, left to themselves, would "not only grow up in ignorance but (would) almost invariably fall into vice because the gratification of doing evil is immediate and apparent while the inducement to abstain is distant and scarcely intelligible to the untaught mind". He then expressed his abhorrence of "the vile language used by children allowed to run wild in the streets", and of the depravity, to the general community, which such language engendered. Nor could the children be blamed for doing what was the result of their neglect. Although he did not think that the locality was any worse, in this regard, than other manufacturing areas, nonetheless, there was much to be rectified and he hoped that the schools would do it.

He reminded his audience that: "In school education, the impressionable minds of the children (were) acted upon by precept and example". Equally, he had firm views on both the place of basic subjects in the curriculum and the importance of good teaching. For instance, he claimed that literature, "where all knowledge is to be found", inculcated habits of industry. Indeed, he averred that: "The greatest of all human inventions is letters. By means of letters, the thoughts and expectations of men are handed down to posterity and thus knowledge goes on accumulating from generation to generation. By the use of letters, we are enabled to give material form to our ideas and exchange them with our fellow men from distant places. Who then would permit a child to remain in ignorance of the use of letters when the means of obtaining the necessary instruction are placed within reach of the poorest parents?"

In his view, the use of letters was the ability to read and write, and on these basic subjects, he had very profound and decided views. He argued that because, in most schools, "these two fundamental accomplishments are too frequently taught in a slovenly and imperfect manner", people were discouraged from practising reading and writing in later life. "If a man can only read as a labour", he maintained, "he will never read for pleasure. If he only writes slowly and awkwardly, he will never write when he can help it".

He argued that merely teaching children to read and write was insufficient, they had to do both, "easily, fluently and correctly". Armstrong was surprised that writing should be taught imperfectly in schools, "because the ability to write well is in itself the means of obtaining a respectable livelihood (while its absence) disqualifies men for many positions they might otherwise fulfil". In consequence, he urged that reading and writing should be well taught.

Next in importance was arithmetic, which "enters into the business transactions of life almost as much as writing, but its acquisition has an excellent effect of exercising and improving the reasoning faculties of the children". Then, with his characteristic view of the future and his philosophy that the best education is self education, he argued that: "Reading, writing and arithmetic open the door of attainment, in mature age, of all knowledge, but without these, self instruction is impossible".

Just as elocution was included in the curriculum of the Elswick Mechanics' Institute, Armstrong argued that it was important for the pupils of the Elswick Schools "to speak their native language correctly". Indeed, in words evocative of George Stephenson, he argued that: "There is nothing which has more effect in determining a man's social position than his mode of speaking". (Newcastle Daily Chronicle 10th April, 1866).

Armstrong obviously attached more importance to sound instruction in basic principles than to inept teaching beyond the rudiments.

Nonetheless, where a boy could be kept at school long enough, lessons in Algebra and Geometry would be valuable "not only as a mental exercise, but also in their application to Science and to many purposes of business". By contrast, he considered that only general ideas in History and Geography were necessary for most purposes in life so long as they gave sufficient stimulus to encourage a child to continue his studies through subsequent reading.

Because the 'Religious Difficulty' had "been a stumblingblock to every scheme of popular education", he insisted that "all church formularies and sectarian tenets be excluded from these schools". By so doing, he hoped to "avoid every controversial subject which might throw an impediment in the way of good secular education".

In Armstrong's view, elementary schools should provide a sound basic education on which more advanced studies could be built and through which, in turn, the faculties of reasoning could develop.

> "The object of school tuition should be to prepare the mind for future acquisition - to furnish it with the tools and implements necessary for its future exercise both in the sphere of business and in the sphere of learning and the several branches of education to which I have referred are especially adapted to effect this object".
>
> "Where time and circumstances permit of education being extended beyond the rudimentary branches, I would give the preference to those studies which develop and train the reasoning faculties, for it is obviously of the greatest importance that men should enter upon life prepared to distinguish between sound and fallacious reasoning. They would then be less liable to be carried away by those who address themselves to the passions rather than to the reasons of the people and who mislead by arguments which educated reasoners easily see to be fallacious. Reason is our noblest gift and our only guide for whatever other guides are presented to us it is by reason that we judge whether they be worthy of our acceptance". (Newcastle Daily Chronicle 10th April, 1866).

In conclusion, he spoke of the manner of funding the Schools. Appealing to the independent pride of his workers, he said:

> "I am sure that I only express the feelings of all respectable mechanics when I say that it would be distasteful to them to have their

children educated as a matter of charity. It would be too much to expect that working men should provide capital to erect the buildings required for the education of their children, but it is only consistent with the independent spirit which marks the great majority of English workmen that they should desire to pay for the tuition which their children shall receive in buildings provided by employers or others for that purpose. In the present instance, a commodious building, divided into schools for boys girls and infants, has been erected free of cost to the workmen, and it only remains for them, by a small contribution from their weekly earnings to meet the current expenses of the establishment. A tax of only two pence a week on the higher paid men, and of one penny on those who receive lower wages, will be sufficient to meet those expenses and afford the blessings of a good education to the children of every man connected with Elswick Works". (Newcastle Daily Chronicle 10th April, 1866).

He then justified his departure from a purely voluntary system.

"Had it been possible to effect so great a benefit by the voluntary payments of those men who should actually choose to send their children to these schools or had it been a case in which the men themselves, and not their children were concerned, I should not have ventured to propose a departure from a purely voluntary system, but considering that there are many men who, from their own want of education, are scarcely sensible of its advantages in the case of their children; and that there are others whose care for their offspring is blunted by the selfishness engendered by intemperate habits, it becomes necessary to remove every temptation to keep children from school and this I fear can only be done by making schools free to all and supported by all". (Newcastle Daily Chronicle 10th April, 1866).

In line with the customary practice of the Elswick Mechanics' Institute, Armstrong announced that the management of the Schools would be vested in a committee, of whom the majority would be appointed by the men themselves. Moreover, all contributors to the Schools would have the advantage of the "free use of the adjacent Mechanics' Institute which is producing such good fruit in the neighbourhood". To those men who had no children of school age, Armstrong appealed to their public sense of duty. "Even if they receive no personal advantage from (supporting the Schools), I trust that there are few amongst the men who make their living in the Elswick Works who would not feel it a sufficient compensation to be the means of rescuing children from degrading ignorance, and saving them from the life of depravity and wretchedness which ignorance and early neglect generally induce". (Newcastle Daily Chronicle 10th April, 1866).

By the time he opened the schools, Armstrong had not only extended his Works at Elswick by diversifying into hitherto untried areas of engineering and ordnance, but was giving unqualified support to the Elswick Mechanics' Institute which he saw both as an educational ladder for the promotion of his employees and as part of an integrated scheme. Was it because he was so ardently setting his own house in order, by ensuring that his workers and their children had both adequate educational facilities and increasing employment opportunities, that he had little time to spare for the continuing wrangling between Durham and Newcastle over the establishment of the College of Physical Science? Only when the opposing factions agreed to settle their differences under the benign guidance of Dean Lake, did Armstrong give the College his support.

Armstrong's shrewd sense of timing was seldom more apparent than in his decision to extend the Mechanics' Institute, to open the Elswick Schools and to support the College of Physical Science when he did. Not only were many of the Mechanics' Institutes impeded by the general lack of elementary education but the enfranchisement of a wider social spectrum made an educated electorate imperative. This emerged as a direct result of the Reform Act of 1867 when the vote was given to the working men of the towns, and a new social class sought political power. Moreover, when an increasing population required more schools for the education of its children this, in turn, endorsed the growing demand for a national system of education. Nonetheless, there was an inevitable time lag between the demand and its realisation, so voluntary agencies filled the gaps. Therefore, it is in the context of the national scene that

Armstrong's initiative, in opening the Elswick Schools, will be assessed.

When the Liberals came to power, in 1868, Robert Lowe became Chancellor of the Exchequer and W.E. Forster took charge of the Education Department in Gladstone's administration. When, in 1870, he introduced his Bill to provide elementary education for the working classes, Forster realised the importance of an educated electorate as the basis of national power. In phrases which Armstrong himself would have endorsed, he argued that: 'Upon the speedy provision of elementary education depends our industrial prosperity. It is of no use trying to give technical teaching to our artisans without elementary education; uneducated labourers, notwithstanding their strong sinews and determined energy, will become overmatched in the competition of the world'. (Hansard, Vol. CXCIX, Col 465, 17th February 1870). In introducing his Bill, Forster had declared the Government's intention 'to complete the present voluntary system to fill the gaps'. Where deficiencies did occur, local school boards were to be elected with the power to levy a local rate specifically for the building of schools and the payment of teachers' salaries.

Improved facilities for training teachers - both Anglican and nonconformist - were introduced when training colleges were opened. The nearest, in the context of Elswick, were three in County Durham. The Diocesan Training Colleges for men and women - later known as Bede and Saint Hild's Colleges - were founded in 1839 and 1858 respectively and were closely associated with Durham University. Darlington Training College, under the direction of the British and Foreign School Society, opened in 1872, as an undenominational college for women teachers.

The pupil teacher system, whereby suitable pupils were apprenticed to teachers, had never been satisfactory, although as the brain child of James Kay-Shuttleworth, it was included in the Committee of Council Minutes of 1846. A former Principal of Darlington Training College sets the system in context:

'Recruitment to the ranks of elementary school teachers during most of the nineteenth century was chiefly from boys and girls already in the schools as pupil teachers. They received little general education, except from the teachers or head teachers with whom they worked as apprentices. Themselves mainly ex-elementary school children, sons and daughters of the artisan and labouring classes, they were in a vicious circle which tightly enclosed "the education of the poor", sealing it off from influences that could give a wider culture. The training colleges gave them their chance of higher education when almost all other avenues were closed to them. But though by modern standards the students were poorly educated they were highly selected from their group and among the best of the Queen's Scholars of their time. College was a rare and coveted privilege, gained only by pupil teachers who worked by day and night to supplement their meagre schooling: teachers by day, pupils by night. On reaching the age of seventeen to eighteen, the pupil teacher sat for the Queen's Scholarship Examination and on the results of this could be considered for admission by the training college of his choice'. (O.M. Stanton, Our Present Opportunities, 1966, pp. 16-17).

Further opportunities for teacher training were created in response to the recommendations of the Cross Commission when, in 1890, Day Training Colleges for prospective teachers were established in seven universities and university colleges. Again, at local level and in the context of Elswick, one of these was attached to the University of Durham College of Science, formerly the College of Physical Science, in Newcastle.

The need for teacher training colleges in the area was acute. No colleges existed between those already mentioned in Durham, and Edinburgh. In Newcastle and Northumberland, the only teacher training facilities were provided by the pupil-teacher system, but even here, Newcastle did not have a central training agency until the Prudhoe Street Centre opened in 1890. (J.C. Tyson and J.P. Tuck, The Origins and Development of the Training of Teachers in the University of

Newcastle upon Tyne, 1971, p. 15). Nevertheless the promoters of the Day College must have been encouraged by the fact that a hundred students applied for the first twenty vacancies. In the present context, a number of Elswick pupil teachers -both boys and girls - continued their teacher training there. The first Principal was Mark Wright, a training college tutor who had taught in both primary and secondary schools, and who, only five years after his appointment as Principal, was made the first Professor of Education in any English University. (Tyson and Tuck, p. 32).

As a result of these developments teaching methods improved and activities were introduced which captured the interests of the child. Over the years, further legislation brought significant developments to the Elswick Schools. For example new subjects, like Physical Exercises and Domestic Economy, were introduced in order to broaden a curriculum already constrained by the system of 'payment by results'.

This system will always be associated with the name of Robert Lowe who, as Vice President of the Committee of Council on Education, made it the cornerstone of the Revised Code of 1862. Details of that legislation need not delay the present argument except to note those factors whose application can be clearly seen in recurring references in the Log Books and Inspectors' Reports of the Elswick Schools. In order to ensure a more competent administration of the Government grants to schools, Lowe adopted as his lodestar two recommendations of the Newcastle Commission Report. Every child, in each grant-aided school, would be regularly examined in the three Rs by one of Her Majesty's Inspectors. Not only did this mean that the teaching of those subjects had a high priority, but the salaries and career prospects of the teachers were, largely, dependent on the results. The consequence was an increase in rote learning, and even inspectors not opposed to the Revised Code, in principle, testified to its stultifying effects. (J. Lawson and H. Silver, A Social History of Education in England, 1973, pp. 290-291). Despite the criticisms of such eminent men as Sir James Kay - Shuttleworth, the system ensured that economic rather than educational factors governed the school curriculum. This continued until the findings of the Cross Commission were published in 1888 and a more enlightened administration came to office. In 1890, Mr (later Sir) George Kekewich was appointed Secretary to the Education Department, while Sir W. Hart Dyke was Vice President of the Committee of Council. (H.C. Dent, "To Cover the Country with Good Schools: A Century's Effort". British Journal of Educational Studies, Vol. 19, June 1971, p. 127).

The Elswick log books suggest that Armstrong's Schools adhered closely to the Government's recommendations, therefore a closer study of the relevant legislation is appropriate.

Before the passing of the Elementary Act of 1870, the various Codes which followed the publication of the Revised Code were, in effect, the codified Minutes of the Education Department. These defined the prevailing conditions under which the Parliamentary grants were to be distributed. However, the terms of the Education Act of 1870 introduced a new ruling:

> 'The Education Department, as occasion requires, may cancel or modify articles of the Code, or may establish new articles, but may not take any action thereon until the same shall be submitted to Parliament and shall have lain on the Table of both Houses for at least one calendar month'. (Report of the Committee of Council on Education, 1872-3, p. xcviii).

If, under these circumstances, the proposals were unopposed, they assumed the power of law.

Thus, the New Code of 1871 became the first of a new series of

Codes, each aimed at simplifying the administration of the regulations; at revising the system of grants and at broadening the curriculum to reflect the current needs of the schools.

Again, in 1871, a more liberal curriculum was introduced which included singing and drill as well as an extended list of 'Specific Subjects of secular instruction'. The list comprised Geography, History, Grammar, Algebra, Geometry, Natural Philosophy, Physical Geography, the Natural Sciences, Political Economy, Languages 'or any definite subject of instruction extending over the classes to be examined in Standards IV, V, and VI and taught according to a graduated scheme of which the inspector can report that it is well adapted to the capacity of the children and is sufficiently distinct from the ordinary Reading Book lessons to justify its description as a "Specific Subject of Instruction" '. (Report of Committee of Council on Education, New Code of 1872, Minutes of Education Department, p. xcviii. Fourth Schedule).

The introduction of Specific Subjects can be seen as a major breakthrough in curriculum development. Indeed, it can be argued that it severed the fetters that bound the elementary school to the mechanical drill of mass produced factory learning and opened the way to the child-centred concept of modern education.

Before the end of the century, the Education Department was issuing instructions to its Inspectors as follows:

'Teachers should not be satisfied unless the instruction in Specific Subjects awakens in the scholar a desire for further knowledge and makes him willing to avail himself of such opportunities as are afforded locally by a Science class, a Polytechnic Institution, a course of University Extension lectures, a Free Library or a Home Reading circle'. (Report of the Committee of Council on Education, 1891-2, Revised Instructions to H.M.Is and Applicable to Code of 1892, p. 224, para 35, Specific Subjects).

This shows a very different set of values from the narrow minded economics of Robert Lowe, whose sole aim was value for money, not a valuable education. Now, at last, the child was being prepared for life. Indeed, can we hear, in the above 'Instructions' the faintest echo of the concept of lifelong learning which is, only now, coming to fruition? The above Report seems to suggest it.

Furthermore, the general report from the H.M.Is for 1891 sounded a note of optimism and trust which was sadly lacking in Lowe's administration.

> 'The greater freedom of classification granted to teachers (a) by making a child's place in the school depend on the teachers' judgement and not on a schedule of passes and failures, and (b) by classification according to attainments in single subjects has been in no sense abused'.

Again, when assessing the effects of the New Code, the Report noted that although it was too early to 'speak with authority and confidence', the signs were favourable.

> 'The results (seem to) corroborate our conviction that it will (succeed) in fulfilling the hopes of educationists that the instruction given will be less bookish, stiff and mechanical, and more productive of vigorous intelligent habits of mind than its predecessors. ---- The freedom of classification, combined with a larger liberty in the choice of subjects and the stimulus of judging the work of the school by the breadth of its teaching rather than by its mere mechanical accuracy must, in the long run, emancipate education from the swaddling bands which have so long cramped its growth, and leave it freer to develop into a higher intellectual life'. (Report of the Committee of Council on Education, 1891-2, p. 352).

Nonetheless, a truly comprehensive system of education had not yet been achieved. As elementary education developed, the absence of an organised system of secondary education led to the establishment of 'higher grade' or 'higher elementary' schools for those pupils who could benefit from a more advanced type of education. When such a school was built by Newcastle Education Committee in Atkinson Road, near the Elswick Works, the new school had an adverse effect on recruitment both in the Works' Schools and the adjoining Mechanics' Institute.

It is in the context of such events, whether at local or national level, that the history of the Elswick Works' Schools will be examined.

Meanwhile, how did the educational facilities at Elswick compare with those elsewhere? A popular criticism of the Mechanics' Institutes was their failure to meet the educational needs of the working class, due to insufficient elementary education. 'It was the general want of any kind of preliminary training which came to be regarded as the greatest of all obstacles to success. ---- The would be instructor of the working man was led to plumb the depths of popular ignorance and to enquire into the nature and extent of the education of working class children, the neglect of which was soon being advanced as the primary reason for the failure of many Mechanics' Institutes'. (Tylecote, p. 92). Given that Tylecote's study dealt with another part of the country - albeit not so remote - and at a somewhat earlier period, were there comparable 'depths of popular ignorance' for Armstrong to plumb in the Elswick Works? If so, did they alert him to the need for a sound system of elementary education, or did he believe that, by providing his own schools to support his Mechanics' Institute, he would not only have a well educated workforce, but he would earn their gratitude and their unswerving loyalty?

As with many studies of the period, the paucity of records makes it difficult to supply valid answers. The only records traced to date are the log books of the Boys' School from 1869-1898; of the Girls' School from 1888 - 1908; H.M.I. and other reports spanning the years between 1869 - 1897, and appropriate references from the Minutes of the Newcastle upon Tyne Education Committee from 1907 to the final closure of the Schools in 1915. Unlike the records of the Mechanics' Institute, the log books give no indication of Armstrong having addressed the Schools or indicating his philosophy for their future. The only such evidence appears in the newspaper accounts of the inaugural meeting, already noted. Nevertheless the log books, and especially the Inspectors' Reports, testify to a dedicated staff and well disciplined children. Indeed, the existing records suggest that the ambience of the Schools bore all the hall-marks of Armstrong's own philosophy for life - hard work and dedication.

These records will be studied against national trends in education and the Government legislation of the time. In general, the log books themselves mirror these developments. Whereas those of the Boys' School are largely indicative of a voluntary school under local and specialised control, those of the Girls' School illustrate the increasing participation by Newcastle Education Committee in its affairs.

However, evidence of the importance of the Elswick Schools, in the wider context, can be seen in Middlebrook's assessment of them shortly before Armstrong's death: 'It was not until 1897 that the accommodation of the Board Schools (in Newcastle) first exceeded that of the voluntary schools. Indeed, in 1889, the Elswick Schools, with two or three thousand names on the books, had by far the largest number of pupils of any school in the city'. (Middlebrook, 1968, p. 287).

The Mechanics' Institute at Elswick had, for some time, been recognised as an avenue for promotion in Armstrong's Works. Thus, in the absence of a national system of elementary education, it seemed natural for Armstrong and his more ambitious workmen to extend the educational facilities by providing schools for the workers' children. Again, the regrettable absence of early records on the schools makes it difficult, either to substantiate this hypothesis or to indicate the source of the idea. Unlike the Elswick Mechanics' Institute, no one individual, like Windlow, emerges in this context. Nevertheless, presumably at Armstrong's instigation, but certainly with his full approval, the Company erected the school buildings and a Management Committee was set up, composed of representatives of the firm and of the men. Apparently, the men were willing to support the scheme by means of a weekly levy on their wages. This levy, which enabled the employees to avail themselves of all the educational facilities available at the Elswick Mechanics' Institute and Day Schools, continued until 1891 when the 'Free Schools' Elementary Education Act was passed. Because this legislation entitled parents to demand free education for their children, the fees at Elswick were reduced to 1d and a halfpenny a week respectively, presumably to enable the work of the Institute to continue.

During the early years the log books show that, despite his many commitments, Armstrong not only supported the enterprise, but regularly brought important visitors to see the Schools. These visits remained a distinguishing feature for at least the first twenty years of the Schools' existence. In September 1869, when the Elswick Institute was host to the Conference of the Northern Union of Mechanics' Institutes, the delegates were invited to visit the Schools. Apparently, the occasion 'gave much gratification. Dr Dodd expressed himself as never being more delighted at having inspected an educational establishment than on visiting the Schools. The boys, he said, were remarkably well behaved and could read and write well'. (Log Books, 6th September 1869). Some years later, 'His Excellency the Minister of China' and his suite, accompanied by Armstrong, visited the Schools. After listening 'with great attention to a lesson on arithmetic and one on Euclid', he not only 'thanked the teachers and pupils, and expressed 'himself pleased with the English method of teaching', but granted the children a half day holiday. (Log Books, 27th July 1877). Again, it was reported that the Mayor of Newcastle and Armstrong accompanied Baroness Burdett Coutts and her husband on a tour of the Schools. The Baroness, herself a social and educational reformer of note, 'was greatly surprised at the extent of the buildings and the large number of pupils and expressed herself as being highly pleased with the good order of the children and the arrangement of the Schools'. (Log Books, 2nd May 1882). In addition, the Elswick Works' Schools appear to have won a reputation for good organisation and academic attainment within the teaching profession itself. Between 1878 and 1882, Headmasters from other schools in Newcastle and district came to Elswick 'to see the working of the school' and expressed their pleasure at the 'good order and high tone' which prevailed there. (Log Books, 1878 - 1882 passim).

Notwithstanding the compliments of the visitors and Armstrong's evident commitment to the Schools, certain questions need to be asked regarding the true nature and value of the education they provided. How far were the aspirations of Elswick's more ambitious workmen and managers reflected in their support of the Schools and to what extent were they realised? What opportunities were there for the children to obtain higher education and consequent career advancement, other than the obvious route of employment in the Works and the Mechanics' Institute? Moreover, in view of the male dominated nature of the Works, how did the type and standard of the girls' education compare with that of the boys? Was it 'equal but different' or was it clearly unequal?

In 1869 the Boys' School was organised under a Headmaster, Mr George Hill, with four assistant masters, one of whom had been trained at the Glasgow Normal School. Two monitors, who earned 2/- per week and later became pupil teachers, completed the staffing complement. (Log Books, 28th April and 16th June 1869). The Management Committee consisted of five members from the Works, including a Mr Thomas Rycroft who acted as Secretary. The Committee appear to have taken their duties seriously, as the log books contain frequent references to visits by them and by the senior managers, like William Cruddas and George Rendel. After one of their regular visits of inspection, their report states that 'the Committee would prefer that Mr Hill refrain from giving instruction to the boys during the time that they are under examination by the Committee'. (Log Books, 16th November 1870).

Nevertheless, Armstrong and the Committee also appeared in a more benevolent role, when, on the eve of the Christmas holiday, each year, they visited the Schools and distributed 'oranges and buns among the boys, who were delighted with the seasonal treat'. (Log Books, 14th December 1869). Each November, Sir William and Lady Armstrong visited the Schools to present prizes for attendance and progress. Then, at New Year, Christmas trees from Armstrong's estate arrived for each department of the Schools. These were 'beautifully decorated, and when lighted up had a gorgeous appearance'. (Log Books, 10th January 1873). Having been allowed to stay away from school while the teachers decorated the trees and prepared the rooms for the party, the children assembled to receive their gifts. This occasion apparently resembled a miniature version of the Mechanics' Institute's annual 'soirée' when the various social classes at the Works met socially and mixed on apparent terms of equality, because the records show that when the boys assembled to receive their treat from Sir William and Lady Armstrong, 'a large number of ladies and gentlemen were present'. The gifts, which seem to have been chosen with the recipient in mind, consisted of 'caps, mufflers, knives, books, writing desks and other appropriate articles'. Not surprisingly, 'the boys were highly delighted with the kind liberality of the esteemed patrons of the Schools'. (Log Books, 11th January 1879).

Does this mean that the Elswick Schools were a mere shadow of the Charity Schools of an earlier age where the children were 'inured to labour'; where a narrow curriculum was taught by rote and where the children showed gratitude to 'their elders and betters' for gifts of clothing which served to distinguish them as recipients of charity? Let the log books speak for themselves.

The records show that the Schools were staffed by teachers qualified according to the system prevailing at the time. Monitors, who were usually chosen from the senior pupils in the school, became pupil teachers at 15 years of age. (Log Books, Minutes of Committee Meeting, 8th April 1872). Nonetheless, from an early stage there is every indication that encouragement was given to the staff to become Queen's Scholars and to obtain formal qualifications in a recognised training college or university.

In the absence of a national salary scale, it is difficult to compare the emoluments paid to the Elswick teachers with those elsewhere. Nevertheless, the records show regular increases being paid to the senior staff of the Boys' School and appropriate remuneration accorded to the juniors in respect of further experience and qualifications. Unfortunately, according to the Girls' School records, the teachers were sometimes paid less when they were employed by Newcastle Education Committee than they would have been by the Management Committee of the Elswick Works. (<u>Newcastle upon Tyne Education Committee Minutes,</u> 5th November 1907).

Evidence of the popularity of the Schools is shown when the numbers in attendance increased to such an extent that it was necessary to build additional classrooms in 1871 and a new Infants' School a decade later. When this was opened on 9th January 1882, the Headmaster was confident that it would be 'a great boon and blessing to the neighbourhood'. Although the records indicate that 'at the beginning of the year the alterations in the Boys' and Girls' Departments were not quite finished', by November 1882 the Headmaster was able to report that 'the new arrangements work very well and the rooms are all full'. (Log Books, 9th January and 3rd November 1882).

These years of expansion at Elswick lasted until Newcastle could build sufficient Board Schools of its own to meet the requirements of the ever increasing population in that particular district. From 1897 onwards the reports show the effect of the opening of the new Board Schools on the number of children attending Elswick Works' Schools and the consequent reduction in Government Grants. In 1897 the annual report indicated that the Grant was '£230 less than the previous year, due entirely to the lessened attendance upon which the Grant is calculated. This is accounted for by the opening of a new Board School in Elswick Lane (which) drew away a number of pupils'. (Log Books, Management Committee Annual School Report, year ending 30th September, 1897). These reports also suggest that the Elswick Works' Schools catered for children living in the district whose fathers were not necessarily employed at Armstrong's factory.

Harsh discipline was not, apparently, a feature of the Schools. The Management Committee regarded corporal punishment as the ultimate deterrent, to be inflicted only by the Head Teacher. According to a resolution passed at the Committee meeting of 10th May 1881, any infringement of their ruling was to be discouraged by the threat of the instant dismissal of the offending teacher. In an age not renowned for its gentleness, their compassion for the children in their care is commendable. Evidence of their uncompromising stand is seen in their decision the following year. As a result of two teachers 'having been caught in the act of inflicting corporal punishment', they were to be given 'a month's notice to terminate their engagement in accordance with the resolution notified to them on 10th May 1881'. (Log Books, 16th September 1882).

In line with other similar establishments, the Schools were regularly visited by Her Majesty's Inspectors and, later, by Inspectors employed by the Newcastle Education Committee. Unfortunately, few of their reports have been traced, but those which remain bear commendable testimony to a well ordered and efficient institution. The first inspection of the Boys' School, which took place within a year of its opening by Armstrong, is a case in point. The Headmaster was reported to have shown 'great intelligence in presenting the boys for examination, having previously been unacquainted with the Government system, and the results are remarkably good'. Moreover, the Inspector acknowledged that: 'although the classrooms are too small, in other respects the premises are very good'. (Log Books, 28th April 1869). A year later, the Inspector again reported on 'a thoroughly efficient' school. He claimed that: 'the discipline is excellent ; the general organisation judicious and the instruction sound throughout'. He further claimed that these factors contributed in no undue measure to 'the very small number of failures'. (Log Books, 20th April 1870). In 1871, he reported that out of 350 boys in the school, 250 were qualified by attendance to be presented for examination. Of these, he reported that about 40% were placed in the upper standards compared with 'the average for my whole district (which is) about 25%. Moreover, 'nearly every boy throughout the school passed with ease'. Although he did not find 'any very advanced knowledge in the highest class', he admitted that the answers to 'plain questions in higher Arithmetic, Grammar and Geography', were 'very fair indeed'. Although the general appearance of the boys also evinced a favourable comment, he gave high praise when he reported that: 'On the whole, there is not a better boys' school in the whole of my district, though there are three where the highest class has a more advanced knowledge in Geography, History and higher Arithmetic'. He further conceded that: 'the accuracy in elementary work is shown by the figures I have given', and gave the unusually fulsome tribute when he claimed that: 'In all my experience, there has been no case of so excellent a result in a large Boys' School'. (Log Books, 31st March 1871). Three years later, a new Inspector also remarked on the excellence of the examination results; of the discipline and of the organisation, while praising the work of the pupil teachers. (Log Books, 7th January 1874).

Unfortunately, such high standards could not be maintained indefinitely. Later that year, the Inspector reported that, while the Geography of the IVth Standard was very good, that of Standard V was 'barely fair'. In the same Standard, 'the map drawing was very poor', although that of Standard VI was 'good'. (Log Books, 12th November 1874). Nonetheless, a year later he reported that: 'the Boys, as usual passed a most excellent examination'. (Log Books, 22nd December 1875).

In 1876, the Inspector reported that he had conducted an examination not only in the three Rs, but in the 'Specific Subjects of English Literature, Physical Geography and Euclid'. (Log Books, 27th November 1876). Remarkably for boys whose future careers lay in engineering, their mathematical skills left much to be desired. This report spoke of Euclid as being 'below fair', while, in the following report, Algebra was only 'very fair' and Euclid 'bad'. (Log Books, 5th January 1878).

The reports for 1881 to 1885 show a consistent pattern. The elementary subjects and Geography obtained good results, but in Mathematics, 'mistakes indicate that the boys trusted to memory rather than reasoning'. Nonetheless, it was remarked throughout the reports that: 'the state of the School is highly creditable to the staff of teachers'. (Log Books, 5th December 1881).

With the growth of the school population, the Inspector noted that: 'The average attendance in the Boys' School (which in the previous year was 699), has been allowed to exceed the accommodation which is sufficient for 641 only'. As a result, 'the School and Class Rooms are excessively crowded, which, in fact, may be said of all three Departments. The proposed occupation of the Lecture Hall in the neighbouring Institute will no doubt afford a temporary relief, but in view of the steady increase in the Elswick Works' population, the Committee are recommended to entertain the scheme suggested at the inspection viz:- the erection of a new School to contain Senior Departments for both Boys and Girls who have passed the third Standard'. (Log Books, 11th December 1885).

The only remaining H.M.Is' Reports were incorporated in those of the Management Committee and submitted to the Heads of School after the Committee's Annual General Meeting.

The report for 1891 is typical: 'Excellently good work - bears favourable comparison with any other in district. Report of H.M.I. last year very gratifying. Highest grant awarded. Report of H.M.I for this year not yet received but Committee anticipate equally good if not better results'. By now it is evident that the schools were gradually losing their voluntary status and were coming into line with the maintained system - a situation which, economically, was not always beneficial. According to the report: 'The Committee have notified the Education Department that they would accept an assisted Grant under the Act passed by the legislature this year; they propose to reduce the subscriptions of the workmen by half and although the Grant is not equal to the amount of income thus lost, they hope by economising in various ways to make up the deficiency'. Although the Committee regretted that their proposal was not approved by certain sections of the workmen, 'the decisive vote given in approval of their actions showed that the workmen, generally, fully appreciated the great good which had, in the past, been done by the several Institutions attached to the Works and which, in the future, is not likely to be lessened'. (Log Books, Management Committee Annual School Report, year ending 30th September 1891).

The high standard continued to be maintained in the following year. The Boys' School again received an 'Excellent' Grant, while the Girls' and Infants' Schools were awarded 'Medium' Grants. Although the actual Report had not been received at that stage, the Committee hoped for even better results than those achieved last year. (Log Books, Management Committee Annual School Report, year ending 30th September, 1892).

In 1893, the Committee reported that the Schools were in a very high state of efficiency and that the Report of H.M. Inspectors was 'very flattering'. All Departments had received 'Excellent' reports and, in consequence, the highest attainable Grants were awarded. This year, apparently, the Schools were exempted from the Examination because their results had been so satisfactory in 1892. (Log Books, Management Committee Annual School Report, year ending 30th September 1893). These results were particularly commendable because there had been a decrease in the numbers of children in the Schools during the year, owing to a reduction in the number of workmen employed in the Works on account of a trade recession. Nonetheless, the Committee, in concluding their Report, praised the work of the School by affirming that: 'great credit is due to the Teaching Staff for the very satisfactory state of the Schools. The work being done is of an excellent character and the organisation and tone of the Schools is all that could be desired'. (Log Books, Management Committee Annual School Report, year ending 30th September 1893). The same Report indicated that: 'Elementary Science is now being taught throughout the Boys' School and an advanced class has been formed for both Boys and Girls in which the following Specific Subjects are taught - Physiology, Algebra, Botany, with the girls taking Domestic Economy as well'. Musical training was also given in this class to qualify pupils for certificates for 'the London Musical College'. (Log Books, Management Committee, Annual School Report, year ending 30th September 1893).

The broad curriculum suggests that the children were not being trained as mere 'hewers of wood and drawers of water', but were being educated in line with Armstrong's own philosophy. As noted earlier, in his address to the Social Science Congress in Newcastle in 1870, and in his subsequent debate with Playfair, Armstrong argued that: "the governance of natural laws" was the best means of enabling a person to reach his own potential. He also spoke of the rewards for those "who possess industry, perseverance and ability", but regretted that many able people were "kept down by want of education". (Armstrong, Transactions N.A.P.S.S. p. 81). To Armstrong's credit, he supplied the means, at Elswick, to satisfy that want.

The reports consistently provide valuable evidence into the working of the Schools, and how they operated under the legislation of the time, especially that usually known as 'payment by results'. For example, in 1894 the Committee was pleased inform the Schools that the highest possible award had been granted to all the departments and the usual high tone and good organisation had been maintained. (Log Books, Management Committee Annual School Report, year ending 30th September 1894).

Several reports are missing, but by 1897 the excellent tone and high state of efficiency were still evident. The Grant awarded by the Education Department for the current year was again the highest. Nonetheless, the building of a new Board School in Elswick Lane reduced the numbers at the Elswick Works' Schools on which the Grant depended. The Boys' Department was described as being: 'efficiently organised and disciplined, and staff generally instruct classes by sound and intelligent methods. Especially creditable is the large amount of good work done in the three highest standards of the school'. Moreover, there was evidence of: 'A very well ordered Girls' School and Teachers discharge their duties with diligence and earnestness. Lessons are productive of generally careful and accurate results'. Equally the Infants' Department was described as being 'under intelligent direction. The teaching is energetic and very conscientious and the children are kindly and sympathetically treated. Unfortunate prevalence of sickness among infants has somewhat retarded their progress'. (Log Books, Management Committee Annual School Report, year ending 30th September 1897).

In 1898 the Committee praised the 'Continued high state of efficiency regarding tone and excellency of work. Grant by Education Department again the highest obtainable'.

The report for the year shows the three departments performing as follows:

Boys. 'This large department is conducted with all its usual vigour and efficiency'.

Girls. 'Taught in a quiet and orderly manner and progress made is equally very satisfactory.'

Infants. 'Recently appointed mistress has excellent control over the School, and Class Teachers secure good order and attention by methodical and interesting teaching. Instruction given is very satisfactory both in amount and quality'. (Log Books, Management Committee Annual School Report, year ending 30th September 1898).

The quality of the teaching is further reflected in the academic attainment of the boys when the number of scholarships to local grammar schools consistently compared very favourably with those of other schools in the area. In 1891, the records show that in the examination of pupils from Newcastle elementary schools for five scholarships to Newcastle Royal Grammar School, four of these were awarded to boys from Elswick Works' Schools. The total value of these amounted to £120, giving an overall total of £330 gained in scholarships by the Boys' school in the past two years. (Log Books, Management Committee Annual School Report, year ending 30th September 1891).

In successive years, 1892 and 1893, one of five similar scholarships, each valued at £30 was won by an Elswick boy, but additionally, in the latter year, the same boy, Edwin Spencer-Smith, also won a Flounders' Scholarship, valued at £40 which was tenable for two years at Barnard Castle School.

In 1894, three boys won Royal Grammar School Scholarships which brought the total value over five years to an impressive £760. Again, in the years 1897 and 1898, two boys on each occasion won similar scholarships, making the overall total for eight years £1,400. One of these boys, Herbert Guthrie, who left Elswick Schools in 1897, joined the Army in January 1917 and was killed near Ypres in October of the same year. (In Memoriam, the Memorial Volume of Newcastle Royal Grammar School dedicated to Old Novocastrians who served in the First World War, n.d. but about 1923,.p. 25).

In addition to the Royal Grammar School scholarships, boys living in the county of Northumberland could compete for Flounders' Scholarships which were tenable at Barnard Castle School. The Committee Reports show that for each of the years 1892 and 1898 one such scholarship, tenable for two years at an overall value of £80, was won by an Elswick boy, whereas for the years 1893 and 1897, two such scholarships were won, including the one noted earlier.

Within this context, what better yardstick against which to measure their opportunities than that of a Royal Commission? Two years after the Elswick Works' Schools opened, the Schools Inquiry (Taunton) Commission reported on the general lack of secondary education in this country.

Locally, they found that: 'In Northumberland, the state of education has, perhaps, varied less during the last fifty years than in any part of England'. (Schools Inquiry Commission, Vol. VIII, General Reports, Midland Counties and Northumberland, 1868, p. 434). They also reported that: 'At Newcastle Grammar School, the education is no doubt good, but it is also cheap, and its cheapness, combined with its quality, has certainly made it very attractive. In the other towns of Northumberland

and in Gateshead, the number of boys attending schools, where something beyond English is taught and paid for, is not large and it would appear that parents generally in these towns are either unable or unwilling to pay for anything beyond the preliminary mechanical subjects'. (Schools Inquiry Commission, Vol. VIII, p. 440). Furthermore, the Commissioners noted that, in Northumberland, 'clergymen and poor professional men who, naturally desire for their children a more expensive education than they can well afford to give them', were almost unprovided for. (Schools Inquiry Commission, Vol. VIII, p. 443). Although some sent their sons, in the first instance, to local Government schools, very few of these offered an appropriate education, beyond the elementary stage, 'at any price at all'. Indeed, they concluded that: 'There is no county in England where so few boys of this class are to be found in local schools'. (Schools Inquiry Commission, Vol. VIII, p. 443).

By contrast, the Commission noted that: 'At Newcastle, the trading population derives the chief benefit from the Corporation's allowances which, since the passing of the Municipal Reform Act, have constituted the Grammar School endowment'. (Schools Inquiry Commission, Vol. VIII, p. 452). Moreover, they reported that middle class education was chiefly supplied by three schools - the Grammar School and two private schools. The names of these two were not revealed, but the description of one which 'had the characteristics of a modern school', suggests Bruce's Academy which, as noted earlier, was attended by Robert Stephenson. Here, according to the Taunton Commission, 'special attention is paid to Physical Science and Chemistry, but instruction is (also) given to about fifty boys in Latin and in Mathematics including a little Trigonometry. Geography, English, History, Grammar and Composition are are subjects of considerable importance'. (Schools Inquiry Commission, Vol. VIII, p.

286).

When Armstrong opened the Elswick Schools, these are some of the parameters within which education was operating in Newcastle. Thus, it is against these constraints that his contribution to education must, ultimately, be assessed. Indeed, it is interesting to note that, apart from Latin, the subjects studied by the Elswick scholars - either in the Institute or the Schools - are the same as those noted by Taunton in the Grammar School and the private Academies of Newcastle. Thus, in the absence of adequate provision for secondary education, Armstrong was meeting an acute educational need.

With the advent of a widening curriculum, in addition to gaining the scholarships, already noted, the boys of Elswick Works' School showed equal prowess in less academic pursuits. At the Committee meeting, held on 10th December 1883, it was resolved that, on a recommendation from the Science and Art Department, freehand Drawing should be taught in the schools. This subject, which would be a useful accomplishment for future engineers in the Works, proved to be very popular. Not only did it receive the 'Excellent' award for the years 1894, 1897 and 1898, but it enabled one Elswick boy to take the prize in an open competition at Shildon in County Durham. (Log Books, Management Committee Annual School Report, year ending 30th September 1897).

From 1894 onwards, the boys had swimming lessons twice a week at the local public baths. Subsequent reports show that the boys soon became proficient both in general swimming techniques and in methods of life saving. In open competition, in 1897, the school team of four boys won the Nestlé's Silver Cup which that firm had recently offered as a means of promoting life saving skills. This award also carried with it the championship of the city. Additionally four silver medals presented by

Newcastle corporation were won by the boys from Elswick as well as two other silver medals and four prizes. (Log Books, Management Committee Annual School Report, year ending 30th September 1897). The following year, the Nestlé's Silver Cup was retained by the Elswick team as well as a total of nine silver medals and other prizes. (Log Books, Management Committee Annual School Report, year ending 30th September 1898).

In so far as the property of the Schools was vested in the Works, events concerning the workmen frequently affected the educational lives of the children. Notable among these were strikes and short time working. Although, in the main, the strikes were of short duration, the Engineers' Strike of 1871 was to have a much greater impact on the lives of the children. For example, on 19th May 1871, the Headmaster could observe that: 'The strike has not affected us much (and) we have a full school', by 7th August he was reporting that 'small pox and the strike have affected the attendance very much'. A week later, the full impact of the strike was felt in the Schools.

First, a false report in The Newcastle Chronicle, stating that the Schools would be temporarily closed, led to a considerable drop in attendance. At the same time, the Head teachers were instructed by the Committee that the Schools were to be commandeered by the Management for the duration of the strike and, in consequence, the children were to be accommodated in South Benwell School. Unfortunately, the records of that school, which would have made an interesting comparison with those of Elswick, have not been traced. As a result of the move, some of the children found the additional travelling to South Benwell School too onerous and left Elswick, permanently, for schools nearer to their own homes.

One such scholar wrote an account of his two years at Elswick Schools for the first reunion held in 1910. A copy of the booklet was presented to the firm by his nephew, Mr G.H. McQueen, in October 1964. On the title page of this particular copy, the latter wrote a useful account of the career of his uncle, and author of the booklet, Mr J.H. Hall. 'The quality of his two years' education at the recently built Armstrong Schools is reflected in the fluency of his writing', observed Mr McQueen. Mr Hall subsequently became a senior partner in an established firm of solicitors in Newcastle, a deputy Lieutenant for Northumberland and a Justice of the Peace. He helped to raise the original Tyneside Scottish Regiment in the Great War and remained its honorary Colonel until his death at the age of 94. It is difficult to prove how typical such a career was, but it serves to indicate that Armstrong's factory was not the only employment open to the children from the Elswick Schools.

The booklet, written specifically for a nostalgic occasion, deals more with happy recollections of schooldays than with an objective account of the educational progress of a school. Nonetheless, it gives a detailed account of sight and scenes - rural as well as industrial - now long departed from Newcastle.

Mr Hall attended the Elswick Schools from 1869 - 1871. When, during the Engineers' Strike, Armstrong brought in workmen from elsewhere, they were housed in the Schools for their own safety. He recalls that, when the scholars were sent to South Benwell School this was 'too far distant for my juvenile feet' so he went to St Mary's School, in Rye Hill, where he completed his schooling. (J.R. Hall, The Armstrong Schools Elswick. Some Reminiscences and Impressions 1912, pp. 5-6). In days before the School Meals service was introduced, he recalls carrying his lunch along Scotswood Road 'which then had a real taste of the country', and, on arriving at school, the lunch was 'heated at the big stove and, though plain and homely, these dinners were fine for young appetites'. (Hall, p. 6).

The boys' literature of the day included weekly papers like: 'The Young Men of Great Britain'; 'Sons of Brittania'; 'The boys of England' and 'Tom Wildrake's Schooldays'. (Hall, p. 18). He spoke highly of the staff, but gave little details of the curriculum, other than a passing reference to general subjects like Arithmetic, Grammar, History and Geography. Of the Headmaster, Mr Hill, he acknowledged that he knew nothing of his qualifications 'though they must have been excellent when the Elswick proprietors entrusted him so thoroughly, but this I can gratefully say, he, at an impressionable age, permanently influenced my life in the right direction by (his) admirable characteristics'. (Hall, p. 20). Such compliments were not accorded to the Inspectors. Recalling one, accurately, by name, he described how 'this unfortunate official ---- took the shape, in our young minds, of the fiend incarnate, the theological Satan becoming dethroned'. Nevertheless, despite the attributes of horns, tail and pronged fork, he acknowledged that 'when the dreaded day came our fears were dispelled, as he proved to be really milder and more human than some of our teachers who, for weeks previously, had been in a state of strain and nervous irritation which more or less affected us, so we were always relieved when exams. were over and school pursued its normal course once more'. (Hall, p. 10).

Although details of the underlying causes of the disruption of the Schools will emerge in the context of the Engineers' Strike of 1871, it is appropriate to note at this stage that, because of the mutual obstinacy of both sides engaged in the dispute, the management brought in workers from elsewhere, who were housed on the school premises.

During October and November, while the Elswick Schools were still meeting at South Benwell, the attendance gradually increased. The Headmaster reported that the absentees 'were a long way behind those who have continued at school all the time. It makes it very awkward for the working of the classes', but added the sanguine hope: 'I suppose we must do our best to overcome it'. (Log Books, 17th November 1871).

In effect almost the whole of the autumn term of 1871 was spent away from Elswick School, but on December 21st, the Headmaster reported their return from South Benwell 'which we have occupied since August 14th'. The sense of homecoming is barely concealed in this particular report, for the Headmaster expressed his pleasure in returning to Elswick, both because he found 'the schools clean and comfortable' and 'on account of their superior accommodation'. Even the School Management Committee did not neglect their duties, for the day after the children returned to Elswick, they attended the schools to distribute their traditional Christmas treat of buns and oranges and, in return, were entertained to a programme of singing and recitation. (Log Books, 22nd December 1871).

In the wake of this euphoria came the realisation of a severe drop in numbers in the New Year, when the Headmaster reported that he had re-entered 15 boys that week, but that 'the schools look almost empty compared with what they used to be'. (Log Books, 12th January 1872).

Fortunately, a later strike, in 1885, was not so prolonged, nor, according to the School Records, did it have any marked effect on the attendance. Not until 1893 was there a report in the decline in the numbers of children in the school which was said to be due to the 'diminished number of workmen employed in the Works' on account of the trade depression'. (Log Books, Management Committee Annual School Report, year ending 30th September 1893).

Few events in the Works had such an adverse effect on the Schools as those noted above. Occasions like the workmen's annual day excursion to Edinburgh and other places of interest caused a temporary drop in attendance at the Schools while the regional celebrations in May 1881 to mark the centenary of George Stephenson's birth resulted in a whole week's holiday for the children.

The following year 'the great International Boat race' which was rowed on the Tyne near Elswick Works, aroused so much interest that Scotswood Road and the other streets in the vicinity of the Schools were crowded with pedestrians and conveyances of all sorts. Because of the apparent danger to the children, many parents did not allow them to attend school. Indeed, so few did come that the Schools were closed for the day. (Log Books, 3rd April 1882). Despite their urban background, the children were invited, annually, to the Newcastle agricultural show - an occasion with which 'all seemed very much pleased'. (Log Books, 16th August 1872 and 24th July 1874).

Equally, events in the wider community caused the absence of teachers - for example, when the Headmaster attended a reception for the new Bishop of Newcastle. (Log Books, 3rd August 1882). When more parishes where established throughout the Diocese of Durham to meet the spiritual needs of a rapidly expanding urban population, the Bishopric of Newcastle was created, in 1882, and the Church of St. Nicholas was given cathedral status. (Middlebrook, 1968, p. 269). The region's leading industrialists, including Armstrong, helped to finance the project. He donated £1,000 towards the restoration of the new St. Nicholas' Cathedral, £500 towards its new organ and another £500 for the Bishopric endowment fund. (Obituary notice, Newcastle Daily Chronicle 27th December, 1900).

Under the system of payment by results, the income of the schools depended on attendance as much as on standards of attainment. Many of the Elswick reports refer to inclement weather as being the main cause of poor attendance, but infectious diseases, many of them seldom encountered in modern schools, were a recurring factor in the competition for adequate Government Grants. In the summer of 1871, as well as the Engineers' strike, an outbreak of small pox in the district reduced the numbers still further. (Log Books, 24th July 1871). As a result, the schools remained closed for a further two weeks after the normal summer holiday in an effort to allay infection. When they reopened on 7th August, the Headmaster reported a very poor attendance.

In the following year, the Headmaster reported that many of the best scholars in Standard VI were leaving the school 'to go into business' and regretted their loss. (Log Books, 30th July 1880). Two years later, he made a similar observation and added that he believed that 'no boy should leave before he has passed Standard VI'. (Log Books, 13th October 1882). Although the Log Books give no reason for the boys' actions, the depression in the Works could have been a contributory factor.

Despite the recurring instances of absence, the Headmaster was able to report in October 1882 that although the lessons were 'very well done', unfortunately, 'much of the good and useful work in the school during the year is never seen'. (Log Books, 20th October 1882). This comment is especially noteworthy in the context of Kay-Shuttleworth's earlier criticism of the Revised Code: 'But is it not a mischievous fallacy to say that the work done is 'to be measured by the proficiency of such children in reading, writing and arithmetic?' (James Kay-Shuttleworth, Four Periods of Public Education as Reviewed in 1832, 1839, 1846, and 1862, 1862, reprinted 1973, p. 584, note 1). Nevertheless, despite continued criticism, the concept of payment by results was the guiding principle of elementary education at that time and was to stultify any real progress in education for many years to come. (P. W. Musgrave, Ed. Sociology, History and Education, 1970, pp. 201-202). The actual working of the system will be considered more closely in the context of the Girls' School.

CHAPTER XIII.

ARMSTRONG'S ELSWICK SCHOOLS, PART II.

GIRLS' DEPARTMENT.

The system of payment by results continued almost to the end of the century, despite modifications, including the consolidation of specific grants into a block payment. Even so, the whole organisation remained highly centralised, with the Education Department in London dealing with each individual board of managers. As the Codes themselves became increasingly complex, the whole administrative edifice was in danger of collapsing. Fortunately, the passing of the Local Government Act of 1888 opened the way for decentralisation in favour of the new County and County Borough councils. By this time, it has been argued, a campaign had been waged 'with growing virulence' by the National Union of Teachers which 'created a climate of hostility to the whole idea of paying for results. (Thus) the grant structure, introduced in 1862 with little opposition and maintained over the years as an administrative expedient went out of existence at a time when its claimed educational values had also been brought into disrepute by teacher propaganda'. (Norman Morris, "Public Expenditure on Education in the 1860s", Oxford Review of Education, Vol. III, No. 1, 1977, p. 4).

Whatever the rights and wrongs of that particular argument, the log books indicate that the Elswick Works' Schools were organised according to Government policy. When George Kekewich was appointed Secretary of the Education Department in January 1890, one of the first tasks awaiting him and the Vice President, W. Hart Dyke, was to frame a New

Code of Regulations for elementary schools. Kekewich recalls working from two main reference points, both of which were in line with his creed that 'the children came first, before everything and everybody', or what, in modern terminology, would be described as 'child centred'.

'The first was to substitute for the bald teaching of facts and the cramming which was then necessary in order that the children might pass the annual examination and earn the grant, the development of interest and intelligence and the acquirement of real substantial knowledge. The second was the recognition, for the first time, of the duty of the State to care for the physical welfare of the children'. (G.W. Kekewich, The Education Department and After, 1920, pp. 53-54).

The Revised Code had recommended that all children should be advanced by 'one standard each year and no more' and that the whole class was to be promoted. This meant that all were taught to one level and that 'the clever children had to mark time while the stupid were being pushed or crammed'. As Kekewich rightly observed: 'Any greater waste of the time and energies of the teacher or anything more disheartening to him could hardly have been invented'. (Kekewich, pp. 57-58).

Now, under the New Code Regulations, the teachers were allowed freedom to classify the pupils themselves. These Regulations were welcomed at Elswick, where the Headmistress reported that she had placed the most able children in each class in the A1 division. It then became the policy of the school, not only to teach them beyond the Code Regulations but, if possible, to advance them two standards the following year. (Log Books, October 1891).

According to the log books there were '1,057 children on the registers of the Elswick Works' Girls' School' on November 1888. Of the

151 new scholars, 110 had been transferred from the Infants' Department and 41 'from outside'. This seems to suggest that children other than those whose fathers were employed by Armstrong were attending the school.

It should be noted at this point that whereas the Boys' School Records are meticulous in giving the appropriate day, month and year throughout, the Girls' Records are less so, in that some give only the month and year. The references quoted here are exactly as shown in the original log books.

In line with the recommendations of the New Code, the Headmistress introduced Physical Exercises into the curriculum. At first 'Drill' was taken for ten minutes each morning 'to improve the deportment of the girls and to form a slight relaxation'. To this end, she sought permission from the Managers to purchase a copy of the 'Drill Manual' for each class teacher. (Log Books, October 1891).

Whereas this request was given a sympathetic hearing, increasing parsimony is shown after Armstrong's death. For instance, a later Management Committee would not reimburse even part of the fees of teachers attending a physical training course in their own time. Furthermore, when the Headmistress was unable to obtain dumb bells for the lower classes she suggested that polished broom handles, cut into six inch lengths, could be used instead. (Log Books, 5th November 1902).

Towards the end of the century, the log books show increasing evidence of an ever-widening curriculum. Apart from the three Rs, which achieved examination results of 92%, the Headmistress reported 'very satisfactory results' in Physiology and Geography as well as in Domestic Economy and Needlework. (Log Books, 28th February 1895). Evidence of the gradual demise of rote learning and the introduction of a more visual and child-centred approach is seen in the Geography lessons. Four years later, the Headmistress noted that map drawing was taught to the three highest standards and that: 'especially good maps are being drawn by Standard VII girls'. (Log Books, 10th March 1899).

Further incentives to use a more visual approach were given by the Inspectors and, again, are reflected in the log book entries. When, on a visit to Elswick, the Chief Inspector advised the Headmistress to introduce an extra subject 'according to the New Code Requirements' he recommended Object Lessons in Elementary Science. Thereafter it was customary for the children to be taken into nearby Elswick Park to study and to draw the plants and animals which had been the subject of their class lessons. Again, in line with Government policy, the children visited local museums and other places of interest and 'wrote good accounts on their return'. (Log Books, 30th May 1902).

Earlier, the Headmistress had observed that a slight change in routine was necessary to allow more time for the teaching of History, 'now an obligatory subject of instruction under the New Code'. At the same time she noted that 'for Standard Ex VII girls who wish to remain longer at school an advanced scheme of instruction has been arranged. In addition to elementary work, Algebra, Freehand Drawing and Domestic Economy will be taught'. (Log Books, 23rd July 1900).

The fact that these girls from working class homes were willing to remain at school after the statutory leaving age and, apparently, were capable of studying such academic subjects as Algebra, Geography and History seems to suggest that there was an urgent need for secondary - or at least higher elementary - education in the area. The boys did have some limited access to local Grammar Schools through scholarships, but there appears to have been nothing comparable for the girls. According to the available records, it was some time before even one girl from the school obtained a scholarship. The girl from Standard VII was 'successful in passing the Scholarship Examination in connection with Allan's Endowed Schools'. (Log Books, 8th September 1899). This award was valued at £15 and entitled the girl to 3 years' tuition without payment of fees. Indeed, the experience of the Elswick scholars, generally, serves to confirm the findings of the Schools' Inquiry (Taunton) Commission of 1868, that the provision of secondary education, especially in large centres of population, was quite inadequate. Within their specific remit, the Commissioners gave considerable attention to the provision of education for girls in Northumberland, and their findings are particularly noteworthy in the context of Armstrong and the Elswick Schools. Although the Commissioners noticed that: 'No educational endowments (in Northumberland) were intended exclusively for girls of a class higher than the labouring class', they did concede that: 'there are endowments to which middle class girls have the same claim as middle class boys. Even in large towns, some shopkeepers' daughters go to private schools conducted by private schoolmasters'. (Schools Inquiry Commission, Vol. VIII, General Reports, Midland Counties and Northumberland, 1868, p. 471). One particular feature noted by Taunton was that, when selecting schools for their daughters, Northumbrian parents tended to: 'prefer solid training in the elements to a smattering of accomplishments, (and they) believe that it is no advantage to a girl to be able to play a tune or draw a copy if she knows nothing of grammar or arithmetic'. (Schools Inquiry Commission, Vol. VIII, General Reports, Midland Counties and Northumberland, 1868, p. 475).

These findings raise the question: 'Did Armstrong's Schools at Elswick have a wider social significance than is at first apparent?' In other words, was he so in tune with the educational needs and aspirations of his workforce that, at the same time as the Commission was meeting, and two years before their Report was published, he provided, not only for the sons, but for the daughters of his employees, an education unequalled in the area until the next century? For example, until the opening of the nearby Atkinson Road Higher Elementary School in 1910, the Elswick scholars - girls as well as boys- did have the unusual advantage of further education in the Day Science classes at the adjacent Mechanics' Institute.

Educationally noteworthy though this situation is, it also serves to highlight the collaboration which existed between the various educational establishments at the Elswick Works at the height of their operational power. For example, when two girls from the Elswick Schools were reported to have passed first class at the Westmorland Road Board School Science Class, the Headmistress observed: 'I think it is a pity that girls who have a desire to study further have not the opportunity of doing so at their own school'. (Log Books, 10th August 1891). In consequence, she suggested that the Managers should consider transferring, to the Day Science Class in the Mechanics' Institute, those girls who passed the Standard VI examination. She considered that 'it would be a decided advantage as the girls could be taught extra subjects which cannot be taught in the elementary school, because all the time is required for preparation in the subjects for the Government examination'. Moreover she understood that: 'boys and girls were taught the same subjects in the Science Classes with the exception of Needlework, which I can arrange'. (Log Books, 10th August 1891). The Managers of both the Schools and the Institute seem to have acted on the suggestion with commendable alacrity. Only two months later the

Headmistress reported that 47 girls who had completed their course in Standard VI had transferred to the Institute.

The Code of 1890 and its successors introduced an increasing range of subjects into the curriculum and these are reflected in the work of the Elswick Schools. Here, the main subjects in this context appear to be Science and Drawing, with Domestic Economy for the girls. This widening curriculum is evident when the Headmistress recorded with satisfaction that the Institute Committee was considering the possibility of teaching Cookery to the girls in the Science class. To this end, she suggested that the Management Committees concerned should consider the appointment of a qualified teacher of Cookery for both the Girls' School and the Institute. (Log Books, October 1891). She also noted that 'in the best Board Schools of the town, Drawing is taken as a Specific Subject, and I am decidedly averse to the Elswick Girls being behind the Board School children in attainment'. Again, her suggestion was acted upon expeditiously, because Drawing was soon part of the curriculum. Unfortunately, she had to admit that 'before the girls in an Elementary School can earn any grant for Drawing, all in Standard IV and upwards must be taught Practical Cookery in a room properly fitted up with suitable apparatus'. In order to limit expense, she suggested that: 'If Cookery be taught in the Institute, I have thought that the one room might serve for both'. (Log Books, 27th October 1891).

Although Domestic Economy was not included in the schedule of 'Specific Subjects' until the mid 1870s, the Committee of Council Report of 1872-3 included a plea for its addition from Her Majesty's Inspector for the North-western counties of England. Commendably, he recommended Elementary Science as well as Domestic Economy, but as disparate subjects rather than as a complete entity. Moreover, he advocated the inclusion of Domestic Economy in girls' schools, 'even to the sacrifice of fractions and decimals'. In line with Armstrong's own views on developing the faculties of reasoning, he suggested that the children should be made aware of 'why' as well as 'how' a system worked, in the hope that such knowledge would equip them for life as future homemakers. Unfortunately, his laudable sentiments bore all the hallmarks of Victorian values and a stratified society when he added the rider that: 'It would be good for the girls to be useful in that state of life to which God has called them'. (Report of the Committee of Council on Education, 1872-3, pp. 111-2). Happily no such restrictive morality appears in the log books of the Elswick Schools. Domestic Economy, like all other subjects in the curriculum, was taught for its educational value, not as a means of maintaining the 'divine stratification of society'.

Meanwhile, the Headmistress had asked for 'the pupil teachers to have a systematic course of instruction in practical cookery from a properly qualified teacher of Domestic Economy. This subject is required for the Scholarship Examination but as there is no examination in it during the pupil teachers' course there is too much to learn in the short time available and unsatisfactory results ensue'. (Log Books, March 1891). At this time, qualified teachers of Domestic Economy must have been extremely rare. The future Training Colleges of Domestic Science, like those in London and Edinburgh, which opened in 1874 and 1875 respectively, and that in Newcastle, which opened in 1880, originated as schools of cookery for 'women of rank', 'women of the working class' or domestic servants. Not until 1893 was the Newcastle establishment taken over by the education authorities of Newcastle and Northumberland as the Northern Counties' College of Cookery and Household Economy. Even then, it was not until 1903 that a two year Diploma course for teachers was introduced, with an optional third year. Thus, in the absence of specialisation, it would be essential for the teaching of Domestic subjects to be undertaken by the ordinary class teachers.

Staffing was a recurring issue in the Schools, although the staff/pupil ratio seems to have been more generous in Armstrong's lifetime than thereafter, when the Schools were increasingly under the jurisdiction of Newcastle upon Tyne. At a special meeting of the Management Committee, convened to discuss the staffing complement of the Elswick Schools, the staff/pupil ratio was considered to be 'greatly in excess of what it should be'. It was therefore recommended that the Girls' Staff should consist of the Headmistress, 8 certificated assistant teachers 5 ex-pupil teachers and 8 pupil teachers. (Log Books, 22nd February 1892). In view of the fact that Standard I consisted of 168 girls taught by a certificated teacher and 2 pupil teachers who had passed the scholarship examination, the existing staff/pupil ratio would not appear unduly generous, even by the prevailing standards of the day. However, the decision was justified when a subsequent reduction in school numbers meant a corresponding drop in class size. Instead of classes in excess of 160 there were now about 86 in a class. (Log Books, 16th February and 8th November 1894). Nevertheless, future entries in the log books indicated that the Head continued to be dissatisfied with the Management Committee's decision. In 1894, after 3 teachers had left the school, she complained that, despite an increase of 11 scholars on the previous year, she had to organise the school with a smaller staff. She then observed that: 'Classes are at present too large for education in the true sense of the word' - a comment which, by modern standards, is more than justified.

She continued to force her argument, almost to the point of blackmail, by reminding the Committee of one of the fundamental principles of payment by results. 'I am much afraid that satisfactory results will not be gained at the year's end unless the children have more individual attention'. She cited the case of Standard IV which was acknowledged, by the staff, as being unusually difficult to teach because of the amount of new work involved. The 169 scholars it contained were grouped into 3 divisions of roughly equal size, according to ability, and she made the not unreasonable request for an experienced ex-pupil teacher, again emphasising that she 'can't guarantee good results with these large classes'. (Log Books, 16th February 1894).

In subsequent years she continued to press her case for more staff, even to the extent of admitting that she was being forced to give the senior pupil teachers classes of 50 instead of the statutory 30. By July 1894, realising that her original request was unsuccessful she asked to retain the services of 2 of her own ex-pupil teachers. Thereupon she was told that if she did so they would receive no advance in salaries due to the financial state of the school. In the event, the two girls in question remained in post only until they obtained more lucrative posts elsewhere. (Log Books, March 1894). Indeed, from this time, until the Schools finally closed, it becomes apparent that the voluntary system, under which they were founded, was in decline and was being slowly, but inexorably, eroded by Government agencies. Nonetheless, despite their own uncertain future, the teachers did not allow the work of the school to suffer. An Inspector's Report of the time shows that: 'Examination of the school gives proof of careful work on the part of the teachers'. (Log Books, 13th December 1897).

When Armstrong died in December 1900, the educational facilities at

Elswick were probably at the height of their operational power. Why, when education was assuming an ever-increasing importance, did the Schools and the Day Science Classes close only 15 years later? In an attempt to find an answer, it is appropriate to consider some of the national and local issues which expedited their demise.

By June 1905, it was apparent that Newcastle Education Committee was, increasingly, in control of the Elswick Schools under circumstances which will be outlined later. Thereupon, the Headmistress noted that the staff had been reduced from 20 assistants to 12. She remarked that: 'Classification cannot be so perfect as it was before the school came under the government of the Education Committee'. (Log Books, 23rd June 1905).

By this time there is evidence of an increasing number of visits by Her Majesty's Inspectors and those of the local authority as well as by members of Newcastle Education Committee itself. This activity seems to indicate that some form of reorganisation was in prospect for the Elswick Schools. The log books for 1904 will serve as a typical example. On one occasion, while the 'Inspector to Newcastle Education Committee' spent a morning in the Girls' School, two 'Government Inspectors visited the schools in order to ascertain the number of children over 14 and under 7 years of age'. (Log Books, 21st January 1904). Early the following term, the 'Assistant Organising Inspector to the Council' paid a brief visit, (Log Books, 11th April 1904), while, some weeks later, the Chairman and Secretary of Newcastle Education Committee also came to the Department. (Log Books, 3rd June 1904). In the autumn term, the Headmistress reported 'visits of inspection' by one H.M.I. and three 'Inspectors to the Council', while Her Majesty's Chief Inspector came and 'paid particular attention to the building and its furniture, etc.' (Log Books, 7th and 13th September 1904). This concern for the actual building and its amenities was compounded when, some weeks later, the 'Assistant Organising Inspector' called to inspect the ventilation and lighting. Apparently, he noted that the school had been fitted with incandescent gas burners which gave 'a very brilliant light during the dark afternoons'. (Log Books, 1st December 1904). Only a month earlier the Headmistress reported that: 'partly owing to the worn out condition of the gas burners, the gas we get in school is exceptionally poor. As we now need gas during the afternoons, it is important that this matter receives prompt attention'. (Log Books, 2nd November 1904). This prompt action suggests that although the Schools were increasingly under the control of Newcastle Education Committee there was no abrogation of responsibility by the Elswick Management Committee.

Similar entries occur each year until 1908 when the log books end. Nonetheless, during that time, the work of the school seemed to progress as usual and the curriculum continued to expand in line with Government policy.

Unfortunately, no further log book entries have been found in order to complete the history of the voluntary school created by Armstrong for the education of the children of his workers. Although this operated before such a facility was available under the maintained system, it became an essential part of the local authority's educational provision until Newcastle could build sufficient schools of its own. Thus, in the absence of log book records, something of the later history of the Elswick Schools, until they closed during the Great War, can be gleaned from the Minutes of Newcastle Education Committee.

The Schools came under the control of Newcastle Council on 30th

September 1903, but the Management Committee at Elswick apparently retained a controlling interest in the buildings and in some aspects of the Schools' administration, though precise details are not defined in the available records. Unfortunately, the teachers appear to have been offered less favourable conditions by Newcastle than those which, hitherto, prevailed at Elswick. Not only were the salary scales still being negotiated between the Education Committee, the Management Committee and the teachers almost a year later, but they seem to have been applied in a most unfair and insensitive manner.

Not every teacher at Elswick was offered a post with the Newcastle authority, and those who were found that the rules pertaining to salaries were most rigorously applied. For instance, some assistants were informed that they only possessed third class certificates and, until they 'passed an examination recognised by the Education Committee' they would only be paid at the minimum salary. Even when they did qualify, the Education Committee was reluctant to pay the increased emolument. (Log Books, 11th October 1904).

On balance, the Elswick teachers lost much more than they gained when the Schools gradually passed from voluntary to public control. As with many others in a similar situation, 'the teachers were now entirely at the mercy of their managers with whom they had to bargain for wages and service conditions in a free labour market'. (Morris, 1977, p.4).

Thereafter, the Schools themselves were increasingly under the threat of closure. From then on, the teachers at Elswick must have felt their insecurity most acutely. This is shown by the fact that the senior staff applied for similar posts to their own in Council Schools, as opposed to voluntary schools. Not only did the Boys' School Headmaster apply for a post in a nearby school, (<u>Newcastle Education Committee</u>

Minutes, 2nd April 1909), but when the Girls' School Headmistress resigned, her post was only temporarily filled. (Newcastle Education Committee Minutes, 3rd May 1909). It was during this Headmistress's tenure of office that the Schools came under the control of Newcastle Education Committee and it was her meticulous entries in the log books not only give evidence of a well run establishment but suggest a high standard of leadership. Firm evidence that the life of the School was on a short lease is seen in the Joint Schools Management Sub Committee's recommendation that: 'Any appointment to the School should be limited to the term upon which the lease of the premises is held by the Committee. The teacher appointed to the post to revert, at the cessation of the lease, to her former position, plus any automatic increases of salary to which she may have become entitled in the interim'. (Newcastle Education Committee Minutes, 3rd May 1909). In the event, the acting Headmistress was appointed 'at the discretion of the Committee for such a period as the school is held on lease' whereupon 'she would revert to the grade of Certificated Assistant, at the original salary plus the equivalent of any automatic increases to which she may have become entitled in the interim of becoming Headmistress and reverting to the position of Certificated Assistant'. (Newcastle Education Committee Minutes, 4th May 1909). Three years later, she was appointed Headmistress at East Walker Girls' School, and the First Assistant from Chillingham Road School became Headmistress at Elswick. (Newcastle Education Committee Minutes, 10th July 1912).

Unfortunately, these bland Minutes give no indication of the trauma endured by the staff in these unstable days or of the educational consequences for the children. Nonetheless, such reorganisation, temporary appointments and staff re-deployment are more readily understood in the wider context of the forward planning of the Education Committee. From about 1906 onwards, these Minutes contained repeated references to:

a) the termination of the lease of the Elswick Works' Schools

b) negotiations for a nearby site on which to build a replacement Council controlled school.

c) the opening of Atkinson Road Higher Elementary School which, under local authority control, was to have such a dire effect on the Elswick Institute.

Some of the earliest indications of a massive reorganisation of the educational facilities in the West end of Newcastle came in a letter from the Board of Education. The Education Committee replied that they agreed with the Board's proposal to recognise the Day Technical Classes at the Elswick Institute, subject to an annual review, but without financial aid. The Education Committee, for their part, made such recognition conditional upon it not being used as an argument against the proposed provision of a Higher Elementary School at Benwell. (Newcastle Education Committee Minutes, 30th November 1906). A few months later, plans for this school, later known as Atkinson Road Higher Elementary School, were submitted to the Board of Education. (Newcastle Education Committee Minutes, 5th March 1907). From then on, the relevant classes at Elswick were closely monitored by both the Board of Education and by Newcastle Education Committee.

As the Government assumed greater responsibility for education, the days of the voluntary principle in education were numbered. Although the work of the Elswick Institute would continue, after the First World War, albeit in a modified form, the Elswick Schools did not survive. By the end of 1910, the Board of Education increased its enquiries regarding Newcastle Education Committee's plans to build a school, under its own jurisdiction, to replace the Elswick Works' Schools. (Newcastle Education Committee Minutes, 31st October 1910). A few months later, in reply to another enquiry, the Education Committee informed the Board of Education that they were still negotiating for such a site, in readiness for the termination of their lease of the Elswick Works' Schools. (Newcastle Education Committee Minutes, 27th February 1911).

Meanwhile, as early as 5th March 1907, Messrs Armstrong, Whitworth sent a letter to the Education Committee concerning the lease of the Elswick Works' Schools, and a sub committee was duly appointed to confer with the Trustees on this matter. (Newcastle Education Committee Minutes, 5th March 1907). Thereupon, it was agreed to lease the Schools for two years in the first instance and on a yearly basis thereafter. (Newcastle Education Committee Minutes, 8th August 1907).

When the Firm was thanked for the sympathetic way in which they had met the Committee's requests for the continued use of the Elswick Schools, (Newcastle Education Committee Minutes, 11th May 1910), they, in turn, indicated their willingness to allow conditional use of the Girl's and Infants' Departments for a further five years. (Newcastle Education Committee Minutes, 30th May 1910).

Throughout 1910 and 1911, repeated enquiries from the Board of Education regarding the future of the Elswick Schools met with the response that the Education Committee were negotiating for a suitable site. Despite the uncertainty of the lease, the Firm continued to renew it, on an annual basis, until 1913. Then, the Firm wrote to the Education Committee indicating their intention ,to repossess the premises when the current lease expired on 1st October 1915, or earlier by mutual agreement. The Committee replied that, although they would find it difficult to comply with that request, nonetheless, in view of the opening of the new Council Schools in the area, they hoped to vacate the premises on 1st January 1915. (Newcastle Education Committee Minutes, 31st August 1914).

When the Firm indicated that they would accept the premises on 1st January 1915 or any earlier date, they were informed that Troops were occupying certain schools in the city, and that it was proposed to allocate the Elswick Schools for this purpose. (Newcastle Education Committee Minutes, 5th October 1914). Whether the Education Committee were entitled to do this, given the leasing arrangements of the Schools, seems doubtful. Nevertheless, this decision was implemented and a scheme of 'double sessions' was formulated to accommodate the children displaced by this arrangement. (Newcastle Education Committee Minutes, 14th October 1914).

At the beginning of 1915, the Chairman of the Education Committee announced that the Elswick Works' Schools, which had been held on lease from the Firm since 1st October 1907 'would cease to exist at the end of the present week as an educational institution'. It was, thereupon, resolved that: 'the Firm be thanked for allowing the Committee to occupy the Elswick Works' Schools up to the present time and that the Director should convey to the Firm the Committee's appreciation of the good work carried on by them at the School for so many years'. (Newcastle Education Committee Minutes, 14th January 1915).

Thus, the Elswick Works Schools closed after being in existence for nearly half a century, and fifteen years after Armstrong's death.

What did they achieve?

When the first School Board was established in Newcastle in 1871, the Elswick Schools, having existed for five years, were among fifteen local voluntary schools receiving Government grants. (Middlebrook, 1968, p. 287). In a town like Newcastle, with a juvenile population of 16,000 aged between five and thirteen, the voluntary agencies were supplying 13,500 places. This fact sets in context one of the stated aims of the 1870 Elementary Education Act: 'To fill the gaps'. Indeed, the Elswick Schools, with between 2,000 and 3,000 pupils on their registers eighteen years later, were more than a mere stop gap. They were an essential part of the educational provision of the area, at a crucial time in our educational history, when the need for elementary education was, at last, being recognised.

W.E. Forster, when introducing the Education Bill to Parliament in February 1870, argued that 'voluntary local agency has failed, therefore our hope is to invoke the help of municipal agencies'. (Quoted in Norman Morris, "1870: The Rating Option", History of Education, Vol. I, January 1972 p. 27). Speaking of the nation as a whole, this might have been true, but how far did this implied failure reflect Armstrong's 'voluntary local agency'? The log books and Inspectors' Reports, already noted, show evidence of a high standard of educational attainment with the children's scholastic and sporting achievements comparing very favourably with their peers in the maintained sector.

The Cross Commission noted that some witnesses had suggested that the Board Schools were subjected to a more rigorous Government inspection than were their voluntary counterparts 'out of compassion for the limited means and inconvenient premises which hamper many voluntary teachers'. (Report of the Commissioners to Inquire into the Working of the Elementary Education Acts, 1888, Chapter XIV p. 343). In the context of Elswick no evidence has been traced to support this view. Although the Commissioners noted a better staff/pupil ratio and better remuneration for teachers in the Board Schools than in the voluntary sector, (Cross Commission Report Chapter XIV p. 341), again, this was contrary to the experience at Elswick. According to the returns of the Education Department more class subjects were taken and more successful teaching was accomplished, with better examination results being achieved in the Board Schools. (Cross Commission Report Chapter XIV p. 341). Nonetheless, the enthusiasm and dedication of the Elswick staff ensured that, as noted earlier, the children would not be 'behind the Board School children in attainment'. (Log Books, 27th October 1891).

Thus, when the lack of preliminary education directly impeded the development of the Mechanics' Institutes, (Tylecote, p. 260), Armstrong met the challenge. He provided schools at Elswick for the children of his employees before the State assumed such responsibility. In line with the parameters set by him in his opening speech, the Elswick Schools maintained a high standard of educational achievement until, with the coming of the 20th century, the voluntary principle was no longer relevant to contemporary needs. Moreover, in a vast industrial complex like Elswick, the exacting standards of school buildings and recreational areas, now being set by the Board of Education, would have been difficult even for Armstrong to accomplish.

Nonetheless, until the Government could realise its goal of 'covering the country with good schools', Armstrong's pioneering achievements, in elementary and technical education, were as noteworthy as his world renowned attainments in armaments and engineering.

CHAPTER XIII.

ARMSTRONG'S LATER YEARS.

When the College of Physical Science opened in Newcastle in October 1871, Armstrong presided at the inaugural meeting which was held in the lecture theatre of the Literary and Philosophical Society. The main address was given by the Dean of Durham, who was also Warden of Durham University, and the event was attended by the Duke of Northumberland and Earl Grey. (Fordyce, 1867 - 75, pp. 167-8).

Meanwhile, three professors had been appointed to the College of Physical Science, and the public appeal had realised £22,000. (Newcastle upon Tyne Council Minutes, 5th July 1871). Thereafter, Armstrong not only served on the Council of the College, but, whenever extra funds were required, his donations far exceeded any others. (Minutes of the Council of the College of Physical Science, later Durham University College of Science, passim).

Nonetheless, his activities continued to be wide ranging. The Mining Institute, now the North of England Institute of Mining and Mechanical Engineers, elected him President in successive years from 1872-75. He was the first mechanical engineer to hold such office.

As always, his Presidential address was forthright, broad based and visionary. Indeed, as with his other speeches already noted, many of his recommendations are still relevant today.

Originally, he observed, the Institute had limited its concerns to the mining of coal, at a time when the mining industry used little machinery and when the northern region was not "so noted for the practice of mechanical engineering in all its branches" as it had now become. Happily the Institute had developed in line with that movement and his own election as President proved that "mechanical science is no longer regarded by members as secondary or merely subsidiary to the practice of mining". Remarkably for an engineer, he warned against "the tendency of the engineering element (superseding) the mining element of this Institute" despite the fact that "we are situated in the very heart of the coal field which, more than any other, has rendered England pre-eminent as a producing nation". Moreover he noted that: "notwithstanding the increasing magnitude and importance of the engineering works of this district, the raising of coal is still foremost amongst the industries of the North". For this reason, although he spoke "as the first President of this Society selected from the ranks of mechanical engineers" he made coal the main object of his address and considered the subject from an economic as well as a technical point of view. (Transactions N.E.I.M.M.E., Vol. XXII 1872-3, p. 39).

First, he called for economy in the production and use of coal, especially by overcoming "the deficiency of human labour by a more extended use of machine labour". Although he argued that the waste of coal, both in domestic and industrial use, was "a threadbare subject", the problem still awaited solution. Coal consumption could be divided almost equally into three main categories - domestic use, steam power and iron making. Although he made reference to the other two, he urged the Institute to address themselves to "the wasteful employment of coal for steam power". He cited his experience at Elswick where, two years previously, he had replaced ten of the original large boilers with two smaller but more efficient ones.

Equally, he outlined the need for economy in coal production, especially in replacing manual labour by machines. Although he conceded that "much has been done in applying machinery for the underground traction of coal and great reduction in both men and horses" he regretted that the "cutting of coal is still almost exclusively performed by human labour". (Transactions N.E.I.M.M.E., Vol. XXII 1872-3, p. 42). Despite the dearth of suitable machines then available, he suggested that, on economic grounds alone, there was the strongest inducement to replace manual labour with mechanical appliances. With his usual capacity for making the impossible seem disarmingly simple, and then presenting a challenge, he suggested that: "the problem does not appear, upon the face of it, to be one of very difficult solution to persons accustomed to mechanical invention and thoroughly acquainted with the conditions under which the work has to be performed". (Transactions N.E.I.M.M.E., Vol. XXII 1872-3, p. 45). In great detail, he outlined the type of machine required, which, in all its essentials, bore a remarkable resemblance to those commonly used in mining today.

In view of later developments at Elswick, it is noteworthy that Armstrong, again, showed his awareness of maritime problems. This time, he naturally emphasised the need for improved engines which would give greater speed using less fuel. "There is no class of steam engines in which economy of fuel is of so much importance as it is in marine engines, for not only is it an object in steam navigation to diminish the cost of coal, but it is a still greater object to save room and thereby increase the space available for cargo".

He then suggested that: "Recent improvements have been almost exclusively directed to the mode of applying the steam, and but little attention has been paid to the mode of producing it". (Transactions N.E.I.M.M.E., Vol. XXII 1872-3, p. 50). He concluded his argument by observing that: "the great number of stokers required in large steamers, the severity of the work and the inefficiency of the method they pursue, as evidenced by the dense clouds of smoke they produce, render the introduction of mechanical firing in such vessels, a matter of the utmost importance and I do not believe that any of the difficulties which appear to stand in the way are incapable of removal". (Transactions N.E.I.M.M.E., Vol. XXII 1872-3, p. 51).

The cordiality of the Vote of Thanks from Sir Isaac Lowthian Bell showed the esteem in which Armstrong was then held by his fellow industrialists and engineers.

'If there had been any doubt existing in the minds of the members of the Institute as to the propriety of confining the selection of its President to (a distinguished mining engineer), such an opinion must have received a complete refutation from the very able address they had just heard from Sir William Armstrong. Your President has entitled himself to that proud distinction which he enjoys as much from the fact of his opinions with regard to the dearness of coal as from his enjoying a very exalted and distinguished position as a mechanical engineer; and it is appropriate that he should have directed his address not so much to the coal owners, not so much to the mining engineers, as to the whole fabric of society at large'. (Transactions N.E.I.M.M.E., Vol. XXII 1872-3, p. 57).

Armstrong's Presidential address to the Mining Institute showed how often he acted as a catalyst - challenging his audience to heights as yet unscaled, and, to the faint hearted, seemingly impossible. Such a leader must have been an inspiration especially to the young men of Elswick at this time.

One young man who joined the Elswick firm within five years of Armstrong's speech was Charles Parsons. After graduating in mathematics at Cambridge, in 1877, he paid £500 to serve his time as a premium apprentice in Armstrong's Elswick Works. Another Elswick apprentice, William Clarke, set up his own firm in partnership with Captain Abel Chapman, making winches for ships, lighting sets, electric engines and motors. Parsons later left Elswick to become a junior partner in the firm of Clarke Chapman in 1884, and took charge of the electrical department. He patented his steam reaction turbine and the firm began to produce turbo-generators commercially. In 1889, Parsons dissolved the partnership and founded his own firm of C.A. Parsons - the now famous Heaton Works of N.E.I. Parsons - in order to develop the turbine yet further. When he died in 1931, his company had built turbo-generators 7,000 times more powerful than his original machine as the major means of producing electricity throughout the world. (Newcastle Journal 29th March, 1986). Seeing the potential of the steam-turbine for maritime propulsion, Parsons had formed another company at Wallsend, Parsons Marine Steam Turbine Company.

Just as Armstrong worked incessantly to produce guns with greater fire power than any then known, so Parsons was similarly committed to producing ships which travelled faster than those currently available. Since, like Armstrong, he preferred to experiment himself, rather than commission one of the many local ship builders, he had to master the art of ship design. Again, like Armstrong firing his first gun over the garden of his home in Jesmond Dene, Parsons experimented with rod and line and model wooden ships on the lake at his home at Ryton on Tyne. His later models, built of rubber, were more sophisticated until, eventually, he produced the first steam-turbine powered ship "Turbinia" which, with a speed of 34 knots, caused such a sensation at the Royal Naval Review at Spithead in 1897.

In view of Armstrong's concern with maritime problems expressed in so many of his speeches, and Parsons' commitment to more efficient and more economical types of ships, the question arises: How far was the Elswick firm, and Armstrong in particular, experimenting with ship design, when the latter made his first Presidential address to the Institute of Mining and Mechanical Engineers in 1873? Although the question is hypothetical, the facts speak for themselves, and seem to suggest that Parsons could have gained valuable experience in marine engineering which, coupled with his own extensive electrical research, enabled him to produce the "Turbinia".

After Armstrong relinquished his appointment at Woolwich, in 1863, it was not until 1878 that Elswick again received further substantial orders from the British Government for modern guns and mountings. By that time, he had realised the potential of overseas orders which his rival, Alfred Krupp of Essen, had seen from the outset. Thus there was potential for a great expansion at Elswick. Because the logical sequence to field artillery was marine ordnance, a merger with a shipyard was essential.

The Low Walker shipyard of Charles Mitchell was further down river from Elswick and, in 1867, it undertook to build ships specifically to carry Armstrong's naval guns. In 1883, the two firms merged to become Armstrong, Mitchell. George Rendel supervised this new operation and designed its first ships. Was this yet another example of Armstrong's unique sense of timing? Three years before Mitchell built ships for Armstrong, a Royal School of Naval Architecture and Marine Engineering was established at South Kensington in 1864 for both fee-paying private and Admiralty students. The latter category comprised 8 naval architects and 8 marine engineers chosen by competitive examination from the dockyards. Among the first eight students were W.H. White, who led the design team at Elswick and his assistant, H.E. Deadman, while a later student, J.J. Welch, was the first Professor of Naval Architecture at Armstrong College, Newcastle. (W.H.G. Armytage, <u>A Social History of</u>

Engineering, 1961, 1976 edition, p. 159). William White, later knighted, was followed by equally distinguished naval architects, including Sir Philip Watts and Sir Eustace D'Eyncourt.

A fast type of cruiser which came to be known as 'The Elswick Cruiser' was first produced for foreign countries. In the 1880s, many guns were made for Italy and, encouraged by the Italian Government, the firm opened the Pozzuoli works near Naples.

Such industrial development must have had an effect not only on Parsons, but, in the present context, on the work of the Elswick Mechanics' Institute.

After the amalgamation with Mitchell's Armstrong virtually retired from active management. Nonetheless, over the years, Armstrong's very success contained the seeds of his own destruction through worsening industrial relations.

Despite all the encouraging signs of expansion at Elswick; despite Armstrong's commitment to building Cragside and his many and diverse interests on the scientific world, shortly before the opening of the College of Physical Science, in 1871, there were rumblings of a pending industrial storm from which Armstrong did not emerge in a favourable light. The stage is set by Dougan:

'Working in an armament factory was tough. Wages were not particularly good. Hours were long, ten hours a day, six days a week. Life expectancy was short. Engineers were dying at an average of 37; their wives at 36. In such circumstances, it is surprising that relations between men and masters remained so good for so long. But now, in 1871, the most serious labour trouble in Armstrong's career erupted'. (Dougan, p. 114).

The nine hour day, which was the cause of this industrial dispute, was part of a recurring demand for shorter working hours. During the first three quarters of the nineteenth century, much of the initiative for reducing the working day came, naturally, from interested pressure groups. (E. Allen, J.F. Clarke, N. McCord and D.J. Rowe, The North-East Engineers' Strike of 1871, 1971, pp. 46-50 passim). Although these movements continued to gain popular support until 1871, many employers, including Armstrong, adopted the view taken earlier by the Rev. J.R. Stephens: 'Let masters and government withdraw or tamper with the Ten Hours' Bill at their peril! Attempt to alter it and the cry will be for EIGHT, or for no time at all'. (Quoted in Allen et al pp. 48-49).

Meanwhile the trade unions had not been idle. The Amalgamated Society of Engineers, founded in 1851, worked consistently to reduce overtime and abolish piece work. Although by 1861 their survey showed that engineers worked, on average, 58.8 hours per week, those in Scotland and North-East England worked much longer. (Jefferys, p. 32). Nonetheless, Robert Stephenson's locomotive works at Forth Banks, Newcastle, had a more enlightened attitude than most firms, including Armstrong's. As early as 1846, draughtsmen there worked worked an 11 hour day, but had one and a half hours for meals and finished on a Saturday at 4 o' clock. Thus they had a 55 hour week. (J.G.H. Warren A Century of Locomotive Building by Robert Stephenson and Co. 1823-1923, 1923, 1970 edition, p. 100).

What were the determinants of the engineers' strike of 1871 and how did Armstrong's attitude compare with that of his fellow employers in the area?

First, there were demographic as well as industrial factors to consider. The middle years of the nineteenth century saw a large population explosion in the North East, mainly as a result of immigrant workers - Irish and Scots - seeking employment in the expanding industries. (Middlebrook, 1968, p. 258). For instance, from 1851 to 1861 the population in England and Wales, generally, grew by 11.9% but in the North East the increase was more than double at 24.2%. (Allen et al, p. 79). This, coupled with the rise of technology, both in the newer engineering and chemical trades and in the traditional coal and shipping industries, altered industrial relations in the area, strained social and cultural relationships, and caused the breakdown of traditional community values. Thus, industrial unrest was a natural corollary. The question was not 'where' would it happen, but 'when'? The obvious place was in the engineering works which had seen the greatest industrial expansion. In the decade from 1861 - 71, Armstrong's outshone the rest, so when the confrontation took place between the North's engineers and their employers, Armstrong and his men were, inevitably, in the forefront.

The length of the working week had been a source of some contention between masters and men for some considerable time, but the success of the negotiations depended very much on the prevailing trade conditions. Concessions which could be won in boom years were impossible during recession. Thus, when the tide turned in their favour, in 1870, the Tyneside engineers took the initiative and pressed for their wages to be paid weekly instead of fortnightly. Encouraged by their success, early in 1871, the men decided to press for the nine hour day which had already been achieved in some other industries. By reducing the existing ten hour day by one hour on Mondays to Fridays they could shorten the working week from 59 to 54 hours. (Allen et al, p. 99).

The Wearside engineers spearheaded the campaign and speedily won their case. Thus, it seemed reasonable to suppose that an equally timely settlement would be forthcoming on Tyneside. Unfortunately, this was not to be. Indeed, the Tyneside engineers' strike of 1871 proved to be one of the most protracted and acrimonious disputes in British industrial history. This was, chiefly, because those employers, like Armstrong at Elswick and Palmer at Jarrow, who headed much larger and more established firms than those on Wearside, were less prepared to give concessions. Important though this dispute is in the history of labour relations, it cannot be ignored in the present context because it highlights the significance of education both to the men and to Armstrong.

When the Nine Hours' Movement opened on Wearside, the men considered two alternative policies. Either they could demand a massive wage increase, which seemed feasible in the boom conditions then prevailing, or they could request a reduction of basic working hours from 59 to 54. Their choice of the latter course was based on the premise that the extra leisure hours would be profitably spent in promoting self help and upward mobility through education, or through healthy leisure pursuits. Such pious sentiments had underpinned many of Armstrong's own speeches, notably those at the Elswick Mechanics' Institute only a decade earlier. Nonetheless, that astute businessman was unimpressed by this display of probity by the workmen and argued, categorically, against it. In his view, the request for shorter hours had less to do with workers' education than with workers' economics. If the working week was reduced to 54 hours, he argued, men who normally worked 59 hours at basic rates could easily work the same hours but with the extra five at overtime rates. This was the stance taken by Armstrong from the outset, and one from which he never wavered.

This again calls into question Armstrong's views on education. Was he really the paternalistic employer, or did he see an educated workforce merely as a means of expanding his empire?

By the end of April, 1871, the Nine Hour Movement had spread to Tyneside and, in particular, to the Elswick Works where one of the leaders, John Burnett, already worked, having been previously employed at Palmers in Jarrow. The men held a meeting in Newcastle on 22nd April 1871, and agreed both to press for the nine hour day or a 54 hour week, and to try to settle the matter by arbitration. Despite the men's reasonable approach, the employers adopted an entrenched position, chiefly because they believed that the men had neither the organisation nor the funds to sustain a long dispute. In the event, nothing could be further from the truth. Indeed, this strike is remarkable not only for the irrevocable damage it did to Armstrong's reputation as the benevolent and paternalistic employer, but as a noteworthy case study in the ability of working men to organise and to survive against all odds.

First, the men formed the 'Nine Hours League' with John Burnett as President. Through this, they organised the campaign and raised and distributed the strike funds. (Dougan p. 115). On 2nd May, they sent their request to the employers. (Allen et al p. 108).

From the outset, the attitude of the men was conciliatory and courteous, compared with that of the authoritarian and dismissive stance of the employers. This is most evident in the first letters exchanged by the two sides. The engineers 'respectfully' hoped that their employers would 'kindly consent to a reduction of the hours of labour --- from 59 to 54 hours per week, a concession that might be made with little or no injury to your own interests and with great advantage to ours'. Equally, they gave an assurance of their 'sincere desire to settle this matter in a friendly and peaceable manner and without recourse to extreme measures' and expressed 'a hope that you will not utterly ignore our claims by treating this with that silence that looks so like contempt'.

(Quoted in Allen et al, p. 108).

In reply, the employers, under Armstrong, not only formed their own association but answered, impersonally, through a firm of solicitors patronised, exclusively, by the local Conservative party. This ultimate insensitivity did little to convince the men that the employers were acting with impartiality.

If the workers found a leader in Burnett, the employers found in Armstrong one as 'notable for his personal prestige in the engineering world (as) for his personal qualities of strong mindedness and determination'. (Quoted in Allen et al, p. 108).

Given the unprecedented expansion of engineering on Tyneside in a few decades, without a major rift in industrial relations, the employers' attitude is as reprehensible as it is inexplicable, especially as a prolonged stoppage must have placed the Tyneside firms at a grave disadvantage in a highly competitive market.

Why did Armstrong, with his vast experience, take this stance? Was he so conscious of his own reputation as a national figure that he thought he could treat the men with contempt? Certainly, his irreconcilable attitude was in direct contrast to the paternalism hitherto shown.

Not every employer shared Armstrong's views. Although Palmer did not agree, in principle, to the shorter working week, he did meet his men, personally, at a mutually convened meeting. Equally, George Robert Stephenson who, since the death of his first cousin, Robert, had succeeded to the family firm, preferred to negotiate directly with his men. Thus, when his employees refused to strike, he responded by granting them the 54 hour week as soon as it was generally accepted on Tyneside.

Among the employers who shared Armstrong's views was Isaac Lowthian Bell who, when giving evidence before the Royal Commission on the Truck System at this time, argued that increased leisure would lead to increased drunkenness. 'The section of the labouring community which desires shorter pay is the improvident and intemperate. For those belonging to this division, any alteration which would enable a workman to increase his visits to the public house would be a misfortune instead of a benefit'. (Quoted in Jefferys, p. 38, note 3).

Meanwhile, the offensive method of communication, adopted by the majority of employers, served only to strengthen the men's resolve. They immediately held a mass meeting to discuss future tactics. Although the unreasonable attitude of the employers was discussed, the men acceded to the advice of their leaders to continue their conciliatory stance and to make a further attempt at negotiation. Despite this, the men from the firm of Clark, Watson and Gurney came out on strike in contravention of the wishes of their leaders. This gave Armstrong and his colleagues a powerful weapon which they used to deadly and precipitate advantage. The Associated Employers issued a second letter through their solicitors, which indicated that they saw 'no advantage in the interview proposed by the Nine Hours League. They would have suggested a written communication from the League in preference to a meeting, but for the fact that a strike had already taken place. Under the circumstances, the Employers feel that no course is now open to them but to refer the Nine Hours' League to their former communication dated the 6th inst. and to request them to consider it final'. (Quoted in Allen et al, p. 113).

A meeting was held by the League on 20th May to consider future action. Here, the pre-emptive strike was severely criticised and a further attempt at negotiation was mooted. Nonetheless, an overwhelming majority voted in favour of strike action, but agreed that the committee of the League must be in complete control throughout the campaign. To this end, they drafted an address for a wide circulation, outlining their case and appealing for strike funds.

Once the decision was made, the leaders of the League were as resolute in supportng the strike as they had been, originally, in its avoidance. On 22nd May, they handed in their strike notices. Of the twelve engineering firms affected on Tyneside, involving 7,500 men, Armstrong's with some 2,700 on strike was by far the worst affected. Clark Watson and Gurney, by contrast, had only 300.

Details of the ensuing protracted and, at times, acrimonious, dispute are irrelevant in the present study, except in so far as they show a different trait in Armstrong's character from that of the benign benefactor seen hitherto. His uncharacteristically obstinate stance is remarkable in the context of his previously stated views on education, especially in regard to the Mechanics' Institute and the Schools at Elswick.

In contrast to Armstrong's maladministration of the affair, John Burnett and his committee conducted a most exemplary campaign. From the outset, the League's leaders argued that increased leisure gave increased educational opportunities, but their pleas fell on deaf ears in Armstrong's case. They even wrote to the Mayor, who agreed to act as mediator between the men and their employers. Burnett's sagacity and reasoned arguments were more than a match for Armstrong's trained legal mind. Using legal tactics to outwit the lawyer, Burnett actually used Armstrong's words to the Northern Union of Mechanics' Institutes as the keynote of his own argument in favour of a shorter working week.

'Indeed, we recollect a case of one employer of labour in Newcastle who, at a public meeting held in the Mechanics' Institute for the purpose of considering the best means of diffusing technical education among working men, expressed his astonishment that more of them did not avail themselves of the means of technical education, which had then been provided, and seemed altogether to forget the fact that in his own extensive establishment the majority of his workmen were working overtime regularly and systematically so that their chance of attending night schools or science classes must indeed have been small, to say nothing of their availing themselves of means of relaxation or bodily exercise, whereby they might revive their worn out physical energies'. (Quoted in Allen et al, pp. 120-121).

Then he highlighted the argument favoured by many employers, that increased leisure meant increased drunkenness.

'We do not pretend that we working men, as a class, are all that we should be. There is a vast amount of ignorance amongst us and a vast amount of drunkenness in our midst; but we contend that one of the most powerful preservatives of ignorance and one of the most seductive agencies of drunkenness, has been the long duration of the hours of labour'. (Quoted in Allen et al, pp. 120-121).

Nonetheless, he emphasised the fact that: 'many working men go to the science class as it is, and distinguish themselves there', but added significantly that 'if many have succeeded under existing cirumstances, many more will be likely to succeed if the hours of labour are shortened'.

Nor did he overlook the need for physical as well as mental education, and the advantages which would accrue to a physically fit workforce.

'Now as to the workman himself, nothing is more necessary than the possession of energy, steadiness and skill, so to the employer the possession of these qualities in the workman is equally indispensable; the interest, therefore of the employer and his workman is one and the same. It is in the interest of both to preserve, for as long as possible, the energy and skill which are of so much importance to both. Long hours of work in an impure atmosphere of a factory are more hurtful than anything else that we know of, and we believe that to this cause is entirely due the large percentage of deaths which occur in our trade from consumption; the average number from that fell disease being about

30%, and the average age of its victims but little over 30'. (Quoted in Allen et al, pp. 120-121).

During their discussions with the Mayor, the League committee showed commendable insight into the commercial prospects and practices of local engineering firms where many jobs were done as piece work. (Jefferys p. 39). Thus, they argued that merely by revising existing working practices, shorter working hours could be attained without increased cost to the manufacturer.

Armed with these proposals and an invitation to meet Burnett's Committee the Mayor attended a meeting of the employers, chaired by Armstrong, but the employers refused to meet the men or even discuss terms.

This refusal gave credence to the case which Burnett and his men were trying to establish namely that mild mannered, reasonable men were facing tyrannical and inflexible employers. Certainly Armstrong played that part to great effect. When the strike notices expired on 29th May 1871, he took the initiative by locking out the remaining men who were prepared to work. (Allen et al p. 125).

In the middle of June, a second source of mediation emerged. When the Social Science congress had met in Newcastle the previous year, Armstrong had addressed the delegates on prominent issues including industrial relations and the Trade Unions. With the strike continuing and no immediate possibility of a negotiated settlement in view, some of the congress delegates tried to put their theories into practice, but in the event, neither party would move from its entrenched position.

By this time, many skilled workers had found employment in other parts of the country and even in America. When, by the end of June, the impasse could not be broken, Armstrong decided to import 'blackleg' labour not only from Britain but from Europe. In order to protect these men from being molested by the strikers, he again showed the same insensitivity that had charactersied his behaviour throughout the strike. He closed the Elswick Schools and used them to house the imported workers. In defiant retaliation, the League held a mass meeting on King's Meadows, which was on the opposite bank of the Tyne from the Elswick Works. Thereupon, Armstrong issued warning notices indicating that when the schools did reopen, only those children whose parents were still employed at the factory would be re-admitted.

It should be borne in mind that Armstrong took this decision not only within a decade of his opening of the new Mechanics' Institute at Elswick when he extolled the virtues of self-help and educational opportunities for the ambitious working classes; not only when he was actively supporting the establishment of the College of Physical Science, which opened within three months; but, above all, in the immediate aftermath of the 1870 Education Act, which made elementary education both a national issue and a national concern. In a career which was so characterised by precipitate action, could any decision by Armstrong have been more emotive? Whatever justification he could offer, his behaviour and that of his fellow employers, throughout the dispute, was ill-timed and ill-considered in the extreme.

As a recent account has noted:

> 'The prospect of a group of wealthy capitalists seeking to defeat thousands of British workmen, who appeared to be striving only for greater opportunities to enjoy constructive leisure, by the use of these brutal tactics, or by the importation of hundreds of foreign workmen struck most contemporaries as essentially unjust and somehow un-English'. (Allen et al p.145)

Because the employers were dealing with engineers who have been described as 'probably the most prosperous, intelligent and closely organised body of working men in the United Kingdom', (Allen et al p. 148), the stalemate continued until, by September, letters and articles were appearing in the national press. By the end of that month, Armstrong wrote, again, to The Times suggesting the intervention of an independent arbitrator. Even this ray of hope was tempered by the observation that: "Two thirds of the whole number have gone away and found employment elsewhere and of the remaining third, probably no more than one half are men for whom vacancies any longer exist. Still it would be wise for both parties to make the best of the matter as it stands and no one would more rejoice than I to see the present contest terminated by a dispassionate and rational compromise". (Armstrong's letter to The Times, 22nd September 1871).

If the loss of earnings to the men had been heavy, the combined loss to the employers of skilled men and valuable orders was incalculable. Thus, the conciliatory tone of Armstrong's letter was not lost on Burnett who eagerly grasped the proffered solution.

When the two sides showed a willingness to negotiate, under an independent third party, A. J. Mundella offered his services. The Liberal M.P. for Sheffield was a manufacturer with a deep interest in industrial relations; was Vice President of the Capital and Labour Committee of the Social Science Congress during its meeting in Newcastle the previous year and, later, became Vice President of the Council, with responsibility for the Education Act of 1880.

But Mundella's diplomacy was no match for Armstrong's obstinacy. Although the League Committee conceded that they would even accept a reduction of wages in return for shorter hours, Armstrong argued that these terms would not encourage the return of the skilled men who had found lucrative employment elsewhere. Instead, he repeated the offer he had made in his letter to The Times that the men could have a reduction in the basic working week of two instead of five hours, and an increase of wages in lieu of the remaining three. This, he claimed, would increase the overall wages bill by 5%, but the present upsurge in trade made this economically viable.

Mundella realised that he was dealing with an intractable situation and withdrew. Later he sent Armstrong a letter in which he urged the need for an arbitration board for the engineering industry on which employers and employees would be represented. (Allen et al p. 171).

Nonetheless, the deadlock had been broken. With further mediation by Joseph Cowan, owner of the Newcastle Chronicle, and the Town Clerk of Newcastle, R.P. Philipson, a peaceful solution was forthcoming. The main terms were that if the employers conceded a 54 hour week, and agreed to pay wages weekly, the men would agree to working overtime only when and to the extent required by the employers. (Allen et al p. 177).

Armstrong expressed his immediate approval, even though it increased his firm's wages bill by 11.6%. The details of the settlement were agreed by Monday 9th October and a general return to work took place on 12th October.

Given that lectures at the College of Physical Science began on 9th October 1871, and Armstrong's generosity had expedited that event, the question arises: What was the nature of Armstrong's commitment to education? During the strike, he had closed the Elswick Schools and, presumably, the 'lock-out' of the men must have jeopardised the work of the Mechanics' Institute. Was he, really, interested in workers' education generally, or only in those who were as motivated and as single minded as himself? Was he guided by social norms or by economics?

Perhaps his obstinacy during the strike provides some of the answers, especially his unyielding assertion that, given the nine hour day, eight hours - or less - would soon be demanded. The modern history of labour relations can be his judge on that count, and has yet to prove him wrong! The six day week of Armstrong's time became five, and in today's leisure orientated society could well become three.

Why did he behave thus? First he considered that the strikers were unrepresentative of the working men and he was not prepared to concede to their demands

He had given everything he had to the firm for 25 years, and expected no less in return. Although born into comparative affluence he made his own way in life in a profession for which he had no training. He made sacrifices, why couldn't they?

Although Armstrong's behaviour was in line with the moral norms of his day, how could it be justified either economically or educationally? The loss to the firm in orders and skilled men who sought employment elsewhere was incalculable. Equally, the closure of the Mechanics' Institute and of the Elswick Schools, affecting the education of innocent men and children, defies explanation.

Was Armstrong so highly principled that he was prepared to sacrifice his reputation on this matter? Or did he accept the short term loss for the long term gain?

The effect of the strike on the work of the Mechanics' Institute would have been mitigated by the fact that these events took place in the summer and early autumn when few, if any, evening classes were functioning. Indeed, judging by the evidence of the Devonshire and Samuelson Commissions, the long term effect seems to have been minimal. Equally with the Schools. Not only would the Newcastle Race Week and the summer holidays cushion the effects of the strike but, with the passing of the 1870 Education Act, Armstrong probably realised that the demise of the voluntary system and the permanent closure of the schools was just a matter of time.

Conversely, there was no diminution in his support of the College of Physical Science. Could this be because he was no longer parochial? He now moved in international circles and was highly regarded in scientific, engineering and educational ones, where he now moved in the highest echelons. Or, in later middle age, was he more at ease in the world of academic research, rather than that of labour relations? Could this be another reason for his unequivocal support of the College of Physical Science, in 1871, when earlier attempts had been ignored?

But times and opinions change and he mellowed with age. Or was it simply that he left the cut and thrust of everyday man management to his young managers while he concentrated on the future? His outlook was always towards the future, and he realised that scientific research, especially electricity, was as much the force of the future - his future - as hydraulics had been that of his past.

When trying to assess Armstrong's contribution to education and science, how better to do so than through the objectivity of Royal Commissions and other official investigations? Such relevant evidence occurs at about the time of the engineers' strike and the opening of the College of Physical Science with the Report of the Select Committee on Scientific Instruction, chaired by Bernhard Samuelson, in 1868, and the Royal Commission on Scientific Instruction, chaired by the Duke of Devonshire in 1871. Somewhat later, though still within the time of Armstrong's influence, came the publication, in 1884, of the Royal

Commission on Technical Instruction, also chaired by Samuelson. Equally noteworthy is the Committee set up in 1878 by the London Livery Companies, which resulted in the founding of the City and Guilds of London Institute, and to which Armstrong was one of the eminent persons invited to give advice on technical education.

Among the witnesses at the Select Committee, apart from Lyon Playfair, were several from the North East whose evidence is singularly appropriate in this context. These included Calvert Clapham, manager of the chemical works at Walker on Tyne, and honorary secretary of the Newcastle Literary and Philosophical Society; Henry Watson, whose Newcastle firm helped Armstrong in the early days of his business ventures; William Cochrane, a local iron master and John Daglish, manager of Lord Londonderry's estates in County Durham who, like Cochrane, represented the North of England Mining Institute.

The Report of the Select Committee noted that:

> 'All the witnesses are of the opinion that it is of incalculable importance economically that our manufacturers and managers should be thoroughly instructed in the principles of their arts. They are convinced that a knowledge of the principles of science on the part of those who occupy the higher industrial ranks, and the possession of elementary instruction by those who hold subordinate positions would tend to promote industrial progress by stimulating improvement, presenting costly and unphilosophical attempts at impossible inventions, diminishing waste and obviating ignorant opposition to salutary changes. Whilst all the witnesses concurred in believing that the economical necessity for general and scientific education is not yet fully realised by the country, some of them consider that the Government should interfere much more actively than it has done hitherto, to promote the establishment of scientific schools and colleges in our great industrial centres'. (Report from the Select Committee on Scientific Instruction, 1868, p. viii).

This four-fold conclusion comprising adequate elementary education for children; technical education for foremen and those in intermediary supervisory grades; higher scientific education in centres of industry for those of managerial rank, and all supported by adequate Government funding, is the best yard stick against which to assess Armstrong's contribution to science and education. It brings into focus the establishment of his own elementary schools and Mechanics' Institute at Elswick coupled with his support of the College of Physical Science in Newcastle. Evidence will be produced later to show his commitment to the last named when, in the absence of adequate Government funding, he, personally, and his firm, collectively, handsomely supported the establishment of the College from the outset.

In his evidence before the Select Committee, Playfair predictably argued that the threat of industrial competition from abroad should be matched by greater opportunities for scientific education in this country. Although this would require a complete reappraisal of the whole educational system, the end would justify the means. 'We have primary schools', he noted, 'but these are not in connection with the secondary schools, and these, in turn are not in connection with the higher schools or the universities of the kingdom. We have, in fact, no general school organisation and therefore I think until you have taken up the subject from the beginning you have no chance of arriving at a good result'. (Select Committee Report, paragraphs 1015 - 1017).

He further argued that it was better to develop existing facilities than to create new ones, especially as there were universities and other institutions, all over Britain, which might well become centres for advanced scientific instruction. (Select Committee Report, paragraph 1026). Even so, like the local representatives, he dismissed Durham as a possible option. When asked for clarification, he replied: 'Though it does teach engineering just now and does pay a nominal attention to science, it was so difficult a few years ago to get them to comprehend science in any enlarged aspect, that I have not much hope of Durham. That university had a splendid opportunity of becoming a people's university for the great manufacturing counties in the North of England, but being governed chiefly by clerical authorities, who perhaps naturally looked to the traditions of Oxford and Cambridge, it has not taken root in the affections and sympathies of the population around it. I was once employed as a Government Commissioner to try to get Durham into a state favourable to scientific instruction, but I found the feeling so unfavourable there that I could do nothing'. (Select Committee Report, paragraphs 1028 - 1029).

How far did Playfair's views equate with those of the local representatives?

When one of them, Mr R. Calvert Clapham, was asked to confirm the existence of a school for scientific education in connection with the University of Durham, he replied: 'No, it is mainly in connection with the College of Medicine. Scientific education at Durham is very deficient indeed'. (Select Committee Report, paragraph 7060).

Clapham's evidence shows Armstrong's contribution to education in the wider context. First he suggested that in the Newcastle area very few schools, even those connected with the large manufacturing works, provided any scientific education. (Select Committee Report, paragraphs 6948 - 6949). His works at Walker, with both day and evening schools, make interesting comparison with Elswick. Of the 2,000 employees, the men paid 2d a week and the boys paid 1d for the upkeep of the day and evening schools. (Select Committee Report, paragraphs 6953 - 6955). He estimated that about 600 boys and girls attended the day schools while 80 to 100 students attended the evening sessions. (Select Committee Report, paragraph 6987). Unlike Elswick, where the Management Committee consisted of workmen as well as supervisors, the schools at

Walker were 'under the management of a Committee, not in connection with the workmen'. (Select Committee Report, paragraph 7071). When asked if other establishments in the neighbourhood had a similar arrangement, he added: 'Sir William Armstrong has ---- and I believe with very advantageous results. But he has extended it. He charges 3d instead of 2d and that includes attendance at the Mechanics' Institute'. (Select Committee Report, paragraph 7089).

Regarding strikes and their effect on education, Clapham agreed that although they diminished the sympathy which existed between employer and employed, he thought that increased educational facilities, both elementary and scientific, 'would be the means of cementing the two interests'. (Select Committee Report, paragraph 7070).

On the vexed question of funding, he praised the work of the Department of Science and Art in raising the standard of education in the country generally, since he did not think that the manufacturers themselves would provide scientific education. 'It is possible', he argued, 'but I fear they would not do it'. (Select Committee Report, paragraphs 7112-7113). When asked if they 'would consider it unfair that they should have to educate not only their workpeople but the community at large?' he replied: 'Yes, we are very fortunate in having Sir William Armstrong who takes an active part in such matters, and there are others who do the same but not many'. (Select Committee Report, paragraph 7114).

Another witness, William Cochrane, who had been educated at King's College, London, was a partner in a family firm with iron works in northern England. As representative of the North of England Institute of Mining Engineers, he was mainly concerned with scientific education for foremen and managers of collieries. Like John Daglish, who also represented the Mining Institute, Cochrane argued that the greatest stumblingblock to further education for miners was the isolation of the collieries, not only from each other but from large towns like Newcastle. Even so, the problem might be solved by using peripatetic teachers. (Select Committee Report, paragraphs 7128-7133). Regarding the standard of efficiency among foremen in engineering establishments, he suggested that the more capable men were to be found in the large establishments 'like that of Sir William Armstrong'. (Select Committee Report, paragraphs 7214-7215). Nonetheless, even these men made mistakes 'from what I might almost call their utter ignorance of the mere elements of science'. (Select Committee Report, paragraphs 7218).

On the question of funding, Cochrane argued that even if the men and the Government were to contribute, he doubted if the mine owners would pay their share, because they considered that the men were earning enough money to pay for the education of their own children. When reminded that some mine owners had built schools and were 'contributing liberally to their support', he argued that in many cases they contributed very little. (Select Committee Report, paragraphs 7161-7163).

He further argued that it was not always easy for employers to provide facilities for scientific study and, in any case, since the country as a whole benefits from a better educated workforce, such responsibility should not rest with the employer but with the Government. (Select Committee Report, paragraphs 7223-7225).

Although the Government had spent large sums of money on the School of Mines, he felt that they were failing in their stated object of instructing young men in mining and engineering. It was better to place such institutions in the centre of the mining industry where what was taught theoretically could be applied practically. Moreover, while he conceded that the great advantage of London was the facility to obtain good professors at low salaries, this was outweighed by the disadvantage of all theory and no practice. (Select Committee Report, paragraphs 7284-7287).

Nor did he consider that the people of the North of England would willingly provide funds for higher education when Durham University had failed to meet the educational requirements of the ambitious industrial classes. He believed that the failure was due to the incompatability of the engineering interests with the present ecclesiastical management. (Select Committee Report, paragraph 7205). Nonetheless, if scientific instruction were to become a prominent feature of Durham University, he was asked whether Durham itself would be an appropriate location or whether a school in Newcastle, similar to the medical school, would be preferable. He thought that both plans were feasible, but that Newcastle was the better venue, even though Durham was very conveniently situated for the whole of the coalfield. (Select Committee Report, paragraph 7206).

John Daglish, mining engineer to Earl Vane, was next called to give evidence in his capacity as a member of the council of the North of England Mining Institute. He took an active interest in the management of Mechanics' Institutes, generally, and, like Armstrong, was a member of the council of the Northern Institute of Mechanics' Instutes. (Select Committee Report, paragraph 7299). He described the educational endeavours of Lord Vane, but these failed to match the more sophisticated provision of Armstrong at Elswick. (Select Committee Report, paragraphs 7317-7319.

Perhaps the most relevant part of' Daglish's evidence, in the present context, concerns the extension of scientific education among the mining community, since it shows local opinion just prior to the founding of the College of Physical Science in Newcastle. No longer did there seem to be a choice between Durham and Newcastle, as in the days when the Duke of Northumberland, Isaac Lowthian Bell and Nicholas Wood were the leading proponents. Now, immediately before the active involvement of Dean Lake and Armstrong, the only possible location was Newcastle.

Daglish obviously supported Playfair's view when he argued that: 'I cannot say that the college in Durham has been any very great success'. (Select Committee Report, paragraph 7354). Nonetheless, when he described the engineering classes there, he acknowledged the academic acumen of Professor Chevallier and the presence of a chemical lecturer. Presumably this was A.F. Marreco who was shortly to be appointed to the College of Physical Science, rather than J.F.W. Johnston, whose work has already been noted.

Like Cochrane, Daglish argued that science schools should be located in centres of industry. Presumably, he upheld Armstrong's example at Elswick, that theory and practice should be studied simultaneously. Nevertheless, he maintained that students who had to travel or reside near a college would prefer to go to London where they would have the advantage of staff of national repute as well as such supporting facilities as museums and libraries at their disposal. (Select Committee Report, paragraph 7352). Even so, he argued that, for engineering as opposed to mining, Newcastle offered great potential. It was the centre of so many large engineering works and, of necessity, young engineers were already residing there. He firmly rejected Durham on the grounds that 'there are no large works and a student could not carry out the two branches of his profession together'. (Select Committee Report, paragraphs 7355-7358).

On the question of financing such a college, the earlier offer made by the Duke of Northumberland was recalled. Although Daglish admitted his ignorance of its precise terms, he understood that the scheme had failed because of the constraints imposed by Durham University. Asked about funding now, whether from Government, coal owners, or manufacturers, he was cautiously optimistic, but he repeated his original arguments that Newcastle was a better location than Durham, and that engineering, rather than mining students were more likely to attend. (Select Committee Report, paragraphs 7359- 7368).

Mr Henry Watson was the only other local resident to be asked to give evidence. Described as an engineer and brass founder in Newcastle, he attended as a member of the Chamber of Commerce. He spoke of his connections with the School of Art, the Newcastle Mechanics' Institute and the Literary and Philosophical Society. Although his firm had given such generous help to Armstrong in the early days, and although he described the educational facilities and lack of funding at the Newcastle Mechanics' Institute, he made no reference whatsoever to Armstrong's educational enterprise at Elswick. (Select Committee Report, paragraphs 7405- 7451).

In general, the Report of the Select Committee highlighted the limitations of the educational system and the dearth of science teachers. As a result, a Royal Commission on Scientific Instruction and the Advancement of Science was appointed. Under the Chairmanship of the Duke of Devonshire, it sat for five years from 1870 - 1875. Among those called to give evidence were Dean Lake, Isaac Lowthian Bell and Armstrong. In each case, much of their evidence concerned the historic arguments about Durham University's failure to develop a strong scientific base. Nonetheless, since they spoke in the summer of 1871, their immediate involvement with the College of Physical Science, shortly to open in Newcastle, makes their evidence doubly noteworthy.

Dean Lake described how, when he first came to Durham, the University was not meeting the educational needs of the district, nor could he see any way to remedy the defect. Moreover, in the forty years since the foundation of the university, circumstances beyond its control had made it almost obsolete. The improvements in rail transport, combined with the increased number of scholarships at the two older universities, made them a more attractive proposition to aspiring young men from the region. Indeed, the founders' hope that Durham would attract large numbers from the North was forlorn indeed. Thus, when Lake became Dean of Durham and ex officio Warden of Durham University, he saw the urgency of making it more relevant to the life and needs of the people of the area. Nonetheless, although a College of Physical Science was a priority, the rival claims between Durham and Newcastle had yet to be resolved.

He recalled that ten years ago, when the Durham University Commission was sitting, even the most learned opinions were equally divided on the subject. Nicholas Wood favoured Durham while Lowthian Bell preferred Newcastle. To the Dean, the educational advantages of Durham seemed, originally, the more desirable, especially when weighed against the alternative of having Durham professors travelling to Newcastle for lectures. Nonetheless, he was greatly influenced by those employers who, standing to lose or gain by the outcome, favoured Newcastle. After taking legal advice, he called a public meeting in Newcastle, when Armstrong acted as Chairman. (<u>Report of Royal Commission on Scientific Instruction</u>, 1872, paragraph 8757).

After giving details of the funding of the college and its association with Durham, he was asked whether the large employers in the district were favourably disposed towards it. He affirmed that they were in favour of its present venue at Newcastle. He then recalled that the debate had raged for some considerable time, and that the Duke of Northumberland had offered a handsome donation, but that the plan had failed because of the intractability of both the University and the employers at that time. Now, he argued, the situation was different. With few exceptions, the employers had responded favourably to the revised plan. Foremost of these, he noted significantly, was: 'Sir William Armstrong, who, if he is interested in anything, always supports it heartily'. (Devonshire Report paragraph 8762).

Unlike Armstrong whose prime concern was the provision of scientific education, Lake envisaged the expansion of the College as a place of general education, biased towards physical science. To this end, he foresaw the appointment of professors of French, German, English language and English history. Otherwise, he argued, tradesmen would fail to support Newcastle as firmly as engineers had failed to support Durham. (Devonshire Report paragraphs 8723- 8775 passim).

When asked the reason for the failure of the previous attempt to found a College of Physical Science, he replied significantly: 'The time for the attempt had not come'. (Devonshire Report paragraphs 8793-8794). Certainly, in Armstrong's case, that seemed an appropriate conclusion. Nonetheless, he did concede that Wood and Bell foresaw the need earlier than some. (Devonshire Report paragraphs 8795-8796). When asked if they were in advance of their time, he gave a very cogent argument. Noting that there were only about seven or eight witnesses called before the Durham Commission, he felt that others might have held similar views but their voices were not heard. Finally, he admitted that the larger employers now realised the value of scientific education, although some refused to support the scheme financially. (Devonshire Report paragraphs 8798-8799). On both these counts, Armstrong had an exemplary record.

In his evidence, Bell briefly recalled the failure of the previous attempt to found the College of Physical Science. By contrast, the idea was now being very warmly received, and already £26,000 of the required £30,000 had been raised. (Devonshire Report paragraph 9150). He felt that the offer of £1,000 a year from Durham University had set the seal on the present movement since it gave the manufacturers the proof they needed of the University's earnest intention to establish the college. His evidence covered much of the arguments already noted regarding the failure of previous plans, but two items are of especial interest in the context of Armstrong. Bell noted that the development in shipping from small coastal vessels to larger ocean liners and from sail to steam had consequences not only for maritime trade but for education. Thus, he argued, the College should plan for a Chair of Navigation as well as making similar provision for engineering and mining. (Devonshire Report paragraph 9154). By this time, Armstrong's firm was working with Mitchell's shipyard at Low Walker and he had already addressed learned societies on the need for greater scientific knowledge applied to navigation. Again, like Armstrong at the British Association, Bell argued that coal burned in blast furnaces was using only 50% of its full potential. Thus, a scientific investigation was required in order to redeem the remainder. (Devonshire Report paragraph 9167). In his view, the manufacturers themselves required a scientific education in order to encourage such developments. (Devonshire Report paragraph 9171).

Although he urged the need for workshop training for an engineer, he agreed with Armstrong that such shops should not be attached to the College, since the apparatus would soon be obsolete. The best place for such training was in a factory where, on economic grounds alone, the tools and machinery had to be of the latest design. (Devonshire Report paragraph 9188).

Armstrong's evidence throws into stark relief not only his own appreciation of the value of scientific education but the importance of Elswick with its own educational system from primary level upwards. Its unique facility was to offer, concurrently, practical and theoretical training in one industrial and educational complex.

Questioned by the Chairman, Armstrong acknowledged that he had taken an active part in the establishment of the College of Physical Science in Newcastle. Equally, he admitted that his experience of the district helped him to appreciate the value of such an institution, both locally and nationally. His motivation for promoting the College apart from "the diffusion of scientific knowledge generally" was because there was "almost a total absence of such knowledge amongst persons engaged in manufactures, mines, agriculture and so on. It is quite manifest that by communicating to those persons scientific knowledge you will enable them to work in the light instead of working in the dark, as they are at present, all their practice being by rule of thumb". (Devonshire Report paragraphs 9202-9204).

Moreover, because they lacked even basic scientific education, Armstrong argued that: "it is impossible to make yourself understood by an ordinary foreman if you attempt to express yourself in scientifc language". (Devonshire Report paragraph 9206).

He acknowledged that manufacturers now realised the value of scientific education and suggested that this, locally, was reflected in their generous support of the College. He then argued the case for provincial colleges rather than those based in London to give students "the greatest possible facility of instruction near their homes". When asked if the sons of manufacturers would take advantage of the opportunities at the College, he thought it "highly probable", although travelling was not such a consideration in their case. "If a local college was as efficient as a central one, there is no question it would be preferred by all classes". (Devonshire Report paragraphs 9217-9221).

Regarding funding, he advanced the view that because of the outstanding generosity of local people, the Government should make an equal contribution, especially when the nation stood to benefit in the long term. When asked if he objected to receiving Government assistance he replied, "Certainly not". (Devonshire Report paragraph 9214).

Although temporary accommodation was already available in Newcastle, he hoped to have "separate buildings appropriate to the College". (Devonshire Report paragraphs 9215-9216). That wish was not only to be realised, but the resultant edifice was to bear his name in perpetuity. He imagined that such a building would be impossible without Government assistance but, in the event, local generosity, including his own, provided the necessary funds.

Asked if, like Bell, he considered that the curriculum of the College should be predominantly scientific, he stated categorically that: "I do not think that there is any difficulty as regards other knowledge but at present there is no means of acquiring scientific knowledge". Thus, while the two manufacturers - Armstrong and Bell - took one view, Lake saw the ultimate objective as a liberal arts college with a science bias. On the recurring theme of combining practical and scientific instruction within the College itself, Armstrong, no doubt with Elswick in mind, suggested that: "practical knowledge is better acquired in the workshops and offices - in actual business, in fact". When pressed further, he suggested that workshops should not be attached to the College. Instead, it should concentrate on "the facility of acquiring theoretical information, such as can be applied to practice in actual business". (Devonshire Report paragraphs 9223-9225).

When questioned about Elswick, he indicated that some young men became foremen as soon as they were out of their apprenticeship, but that was "a rare exception". Nonetheless, because these young men "seldom stop at being foremen, they go still higher", he envisaged that, in future, they would pass through the College before becoming apprentices. On the whole, the course would be completed by the age of 16, but he hoped they would continue their studies in the evenings. "At our own factory, we have night classes especially for the young men and apprentices". In arguments evocative of those used during the Engineers' Strike, he dismissed the problems of studying after a day's work as being "not difficult to a healthy young man". He contemplated having night classes in the College, because he considered them to be an important part of the system, but they would be directed mainly towards apprentices who were employed during the day. He recalled that: "At Elswick, a great number of our young men avail themselves of the night classes. We have there a Mechanics' Institute in combination with schools for primary education and in this institution we have tuition in all branches of practical science in the evenings. Those who distinguish themselves at those classes never fail to be brought forward into the drawing offices and so on. That may be considered as a test of what would be the case if they obtained similar instruction at evening classes at the College. People would naturally select those who had distinguished themselves at those night classes". He affirmed that preference was given at Elswick to those with some scientific knowledge. "Certainly we are always on the look out for those who display any aptitude and any superior progress". Asked if any advantage would be gained in employing such men in preference to those who merely worked by rule of thumb, he replied: "Yes, we are guided by our own interest in doing so; that is the principal inducement. Of course, one would naturally like to put forward deserving young men for their own sakes as well". (Devonshire Report paragraphs 9226-9235). This small piece of evidence, given at the time of the Engineers' Strike, succinctly encapsulates both the extent and limitations of Armstrong's contribution to science and education. In his view, there was no better model for scientific and technical education than Elswick. Although it combined the ultimate union of theory and practice in one place, in the final analysis, economics over-ruled education.

Sir James Kay-Shuttleworth, as a member of the Commission, pressed Armstrong further for his views on the inter-relationship between theoretical and practical instruction, especially as an earlier witness, Mr Platt of Manchester, had suggested that practical work in a factory should alternate with two years' theoretical study over an eight year period. Armstrong argued that: "If we had nothing to consider but the education of the young man, it would be a very good thing, but I do not think that his employer would approve of that interruption of his duties".

Although Platt had further argued that if a young man was unsuited to a particular type of employment, it seemed pointless for him to spend two years studying science before encountering the rigours of a workshop, Armstrong took the opposite view. "If he had become accustomed to mere practical employment, he would not readily take to theoretical study". Kay-Shuttleworth then suggested that if the youth were to receive two years of scientific instruction, immediately after his purely theoretical instruction in school, he might be unfitted for the harsher experiences of the factory. Armstrong conceded that "there may be something in that. I think that young men at universities at all events are liable to acquire fastidious habits that do in some degree disqualify them for the rough life that they would lead in a workshop". (Devonshire Report paragraphs 9240-9241). He thought that young men should "enter their business at a tolerably early age before their habits are too much formed. No man who is to battle with the world ought to be later than 16 or 17 in entering upon his employment and therefore, I think, whatever education is to be acquired should be mainly, at all events, before that. I think he can very easily keep up his studies at his leisure, after that, provided that facilities are given". He doubted whether it would be desirable to interrupt his employment to go to the college a second time, as Platt suggested. "I scarcely think that that would answer - certainly not as a rule - it might do in particular cases where it was desirable to complete the highest possible amount of scientific education". Again, speaking from his experience at Elswick, he thought that "pupils who pay a liberal premium on entering a factory might pursue that course with advantage and of course the premium would cover whatever disadvantage to the employer there might be by taking a young man upon those terms". (Devonshire Report paragraphs 9242-9243). When Kay-Shuttleworth acknowledged that Elswick was the noteworthy exception, Armstrong affirmed that, elsewhere, a young man normally entered the office of an engineer or a manufacturer and learned what he could in the daily routine of business. Thus, he qualified himself to become a foreman, a manager or a partner, without attaining any real scientific instruction. (Devonshire Report paragraphs 9237-9239).

Regarding funding, Armstrong did not think that the proposed 5 guineas to be charged for each course at Newcastle would be a deterrent, since such a sum was "quite within the reach of any well to do workman, foreman and so on. I think that there would be few persons in that capacity and upwards but that would avail themselves of it and whenever a young man shows a great deal of talent at school, he generally finds somebody to help him a little". (Devonshire Report paragraph 9248).

When asked if he was satisfied with the arrangements for practical instruction in the chemistry and physics laboratories at Newcastle he admitted that the situation would be monitored. Meanwhile, they had appointed a professor, but many arrangements were still to be finalised. Although there were rooms and funds already available for the scientific apparatus, he was sure that the College would be "much more efficient if we had larger funds, and with that view a little Government aid would be very valuable". Despite the generosity of the funding, he admitted that: "It is just as much as we can do to set it going by the means we have at our disposal and these means I consider represent a capital of fully £60,000". As it was, the annual income would be spent mainly on professors' salaries, and it was hoped to increase their number before long. When asked if an application for funding had been made to the Government, he admitted that it was still "merely a subject of conversation". Nonetheless, they had the necessary funds to open the College in October of that year. (Devonshire Report paragraphs 9249-9254).

He admitted that he had very little knowledge of continental practice, except that he understood that: "local colleges like Newcastle are much more frequent on the continent than in England". (Devonshire Report paragraph 9236). Equally, he acknowledged a lack of personal acquaintance with Owen's College, Manchester, but he understood that it "was established chiefly with a view to scientific education (which) you can't get anywhere, hardly, certainly not from local sources". (Devonshire Report paragraphs 9256-9257). To this end, he agreed that the establishment of a "considerable number of such colleges" was essential, especially in the manufacturing districts where the northern area alone required another 3 or 4 with Manchester, Newcastle and Leeds as the main centres. (Devonshire Report paragraphs 9258-9259).

It is notable that while others confined their arguments to mining and engineering, Armstrong, although an engineer himself, took the broad, visionary view and included agriculture - a subject for which the Newcastle College was soon to be renowned.

He considered that there was "a great want of such institutions all over the country, in the great manufacturing populations and even in the agricultural districts, because science is very intimately connected with the most advantageous mode of cultivating the ground. In fact, in every way whatever, the productive power of the country must be enormously increased when you can bring scientific knowledge to bear upon it". (Devonshire Report paragraph 9255).

When asked how well the agriculturalists had encouraged the College at Newcastle, he replied: "In some degree they have, but I do not think that they are so much alive to the importance of it as manufacturers are". (Devonshire Report paragraph 9260). Nonetheless, he was confident that once the College was established, the larger farmers would support it by sending their sons there. (Devonshire Report paragraph 9261).

Throughout his evidence, Armstrong's attitude to education is patently apparent. In his view, no better system than Elswick could be found, for the scientific instruction of apprentices. There, theory and practice intermingled concurrently, on a daily basis, without dichotomy. Nonetheless, he was no social reformer, and underlying all his plans, the balance sheet was paramount.

CHAPTER XIV.

ARMSTRONG AND SAMUELSON.

In many respects, the Devonshire Commission was the most satisfactory of all the educational enquiries of that time. Indeed, had its recommendations been implemented, its contribution to science would have been incalculable. Unfortunately, despite the competition from Europe and America, British industry was slow to adapt to modern scientific techniques and their practical application. Among employers and workers alike, there were still pockets of resistance to the advancing wave of science and education as well as a lack of mutual esteem between the men of practice and the men of theory. Nonetheless, the evidence before the Devonshire Commission, and borne out later by Samuelson, suggests that Armstrong was pioneering at Elswick the type of concurrent practical and theoretical training which should have been standard national policy.

Lack of research and the paucity of technical education were highlighted by the Devonshire Commission. Despite indifference in industry and the unwillingness of Government to spend money on such projects, there were those proselytes committed to advance the cause. Playfair, who was not only an academic but an industrial scientist, saw more clearly than most that Britain's prosperity rested as much on an injection of science as on industrial acumen. He argued that: 'the establishment of industrial colleges will materially aid the progress of science by creating positions for its professors and for those who would willingly cultivate science, but are scared from it by the difficulties they have to encounter in its prosecution'. (Quoted in Cardwell, p. 81). That argument is the context in which the two Royal Commissions, (Devonshire and Samuelson) should be noted and in which Armstrong's involvement with the College of Physical Science should be assessed.

Fortunately, a significant change of direction occurred when A.J. Mundella was appointed Vice President of the Council in 1880. An exponent of technical education, he welcomed H.M. Felkin's pamphlet on industrial education in Germany, published in 1881. Supported by other proponents, Mundella pressed for the establishment of a Royal Commission on Technical Instruction. Chaired by Bernhard Samuelson, it sat from 1881-1884 with a remit to compare industrial education here with that abroad. The Commissioners, all of whom advocated technical education, took their responsibilities so seriously that they visited foreign as well as British establishments, interviewing employers and workers alike.

Most European industrialists, having had the benefit of technical education themselves, were firm advocates of the system. Nonetheless, in one respect, as the Samuelson Commission discovered, British technical education was supreme. The evening classes, under the direction of the Science and Art Department and, latterly, of the City and Guilds of London Institute, were unique. But this was an exceptional phenomenon. By contrast, with the experience of the early Industrial Revolution and the national propensity to seek an immediate return on capital outlay, British employers were slow to adapt to more scientific practices. Of the few who did, Armstrong's example at Elswick was noted as much by Samuelson as by Devonshire.

Why Armstrong did not appear before the Royal Commission on Technical Instruction is purely speculative, although there is abundant compelling evidence to suggest the answer. Essentially a business man, Armstrong avoided, where possible, what he saw as mere debate, especially when, at the time of the Samuelson Commission, he took the next logical step in ordnance, through his deep personal interest in warship construction. Nonetheless, the firm collaborated, most willingly in replying to the questionnaires of the Commissioners. (See Appendix VIII).

With his characteristic sense of timing, he saw the need for swift, manoevrable ships with devastating fire power, in preference to the more ponderous heavily armour-plated vessels. As the Samuelson Commission were starting their deliberations, Armstrong and George Rendel were designing the world's first protected cruisers, capable of withstanding the newer powerful naval guns, without losing essential speed and mobility. The prototype vessels with a top speed of 18 knots were built in the Walker shipyard of Charles Mitchell and Company, in 1882-3, just before the two firms merged. Moreover, the River Tyne Commissioners, of which Armstrong's father had been a founder member, undertook a series of improvements in the dredging and maintenance of the river, which had far reaching consequences for Elswick. Not only was the whole island, opposite the Elswick Works, and known as King's Meadows, removed, but in 1876, the Tyne Commissioners demolished the stone Tyne bridge at Newcastle which, hitherto, had prevented access by larger ships to the higher reaches of the river. The way was now open for a vast expansion at Elswick and Armstrong, as usual, readily seized the opportunity. First, he replaced the demolished bridge with the new Swing Bridge, whose centre span operated by hydraulic machinery and allowed even the largest ships to pass unimpeded between Elswick and the mouth of the Tyne. This heralded the opening of the new Elswick shipyard which launched its first ships in 1885. Because this development coincided precisely with the Samuelson Commission, Armstrong would have been most reluctant to give evidence in person. Nonetheless, this new venture had the most positive repercussions for technical education, especially for the Elswick Mechanics' Institute and for the College of Physical Science, which soon developed its own Department of Naval Architecture, as a direct result.

By contrast, Bell did give evidence before the Royal Commission. As the College of Physical Science had been operating for more than a decade, his views are particularly valuable in that context. After outlining its history, he indicated that, although he was being questioned mainly on the iron and steel industry, the curriculum of the College covered a much wider field. Indeed, by the time of his evidence, in February 1882, there were already six Chairs in scientific subjects, namely: Pure and Applied Mathematics; Chemistry; Experimental Physics; Geology; Natural History and in Coal and Metal Mining. He further indicated that, despite judicial investment of the original funds, the College was still in temporary accommodation, making the lack of permanent laboratories a major problem. It had been hoped that the enthusiasm engendered in the previous year, during the centenary celebrations of George Stephenson's birth, would have resulted in greater support for the College. In the event, only £4,000 had been promised from about half a dozen subscribers. In consequence, Bell thought that colleges should be established through Government funding in areas of greatest need. This would overcome the problem of those manufacturers who failed to support such schemes. (Report of Royal Commission on Technical Instruction, paragraphs 288-90). Remarkably, he was unaware of the efforts made by the City and Guilds of London

Institute to establish technical classes in different parts of the country, especially when Huxley praised Armstrong's initiative in pioneering such classes at Elswick, in Bell's own specialism of iron and steel manufacture. (See Appendix VIII and Huxley's evidence paragraph 3005).

Awareness of the lack of mutual respect between the men of theory and the men of practice is implicit in some of the questions posed by the Commissioners, especially when Bell was asked for his opinion on the utility of school instruction in practical work in the iron industry. Despite his own education at Edinburgh University, he was always sceptical about the merging of theory and practice. On this occasion he considered that: 'In the manufacture of iron such a thing would be impossible. You could never expect to set up a school containing a blast furnace and a rolling mill, but generally I should consider that importance ought to be attached to getting people into the works when they are young enough to be willing to learn and before they know a great deal more than the rest of the world'. (Samuelson Report, paragraphs 302- 303).

Nonetheless, the most noteworthy evidence in the present context is that of Professor T.H. Huxley, since it makes specific reference to Elswick. In his view, employers of labour should assume some responsibility for scientific education, especially when enlightened self interest, alone, would encourage them to provide greater educational opportunities for their workers. He then praised Armstrong's initiative:

> 'I know, for example, that Sir William Armstrong has considered it his business and duty to develope a system of scientific instruction at Elswick. They have one of the best elementary science schools extant in Elswick, and if employers, besides establishing such schools accessible to their work people, would show that sort of practical interest in the matter which might be shown, if they would allow the more intelligent of the scholars some privileges in the way of extra time, or some kind of reward for doing well, the encouragement to technical education would be very great'. (Samuelson Report, paragraph 3000).

Perhaps with Armstrong's example in mind, he acknowledged that there were 'many honourable exceptions', yet he still argued that the vast majority of employers were not only indifferent to the merits of technical education but maintained a 'miserable sort of jealous feeling about the elevation of their workmen'. He further maintained that, as Armstrong discovered at Elswick, the advancement of technical and scientific education would be greatly enhanced when 'employers showed that they valued it and that they would do something for the young people who in any way distinguished themselves'. (Samuelson Report, paragraph 3000)

He was then asked if employers should institute and support classes in connection with the Science and Art Department, especially if such classes could be made more relevant to their own needs than at present. In an argument redolent of Armstrong's earlier letter to the Livery Companies of London, (See Appendix IX), he suggested that, given the present level of science, such action would merely result in rote learning. Indeed, he claimed that: 'the knowledge (the scholars) possessed would be nothing more than a little of the ordinary technique of their business, varnished over with scientific phraseology'. (Samuelson Report, paragraph 3001).

The Commissioners obviously regarded Armstrong's initiative at Elswick as a blue-print for emulation. Philip Magnus, Director of the City and Guilds of London Institute, asked Huxley: 'Have you heard that Sir William Armstrong has a class at Elswick in which students who have passed through a general training in science receive special instruction in the metallurgy of iron and steel, this class being in connection with the City and Guilds of London Institute?' Unlike Bell, who, remarkably for a local iron-master, was unaware of these initiatives, Huxley had been fully briefed. Nonetheless he felt that: 'while I quite agree with you that an examination devised upon that plan would be an admirable thing, I have my doubts whether that is the business of the State. I think it would be better done by employers and persons specially interested in technical education.' (Samuelson Report, paragraph 3005).

In their conclusions, the Commissioners made the following points: 'Not many years have passed since the time when it would still have been a matter for argument whether, in order to maintain the high position which this country has attained in the industrial arts, it is incumbent upon us to take care that our managers, our foremen and our workmen, should in the degrees compatible with their circumstances, combine theoretical instruction with their acknowledged practical skill. No argument of this kind is needed at the present day. In nearly all the great industrial centres --- more or less flourishing schools of science and art of various grades, together with numerous science and art classes, exist and their influence may be traced in the productions of the localities in which they are placed'. Among a list of six examples cited, they acknowledged that: 'the schools established by Sir William Armstrong at Elswick --- testify to the importance attached by employers to the theoretical training of young mechanics'. Equally they admitted that many Mechanics' Institutes 'are now largely remodelling their constitutions in order to bring up their teaching to the level of modern requirements, as regards technical instruction'. (Samuelson Report, Conclusions Part IV, p. 513).

Other conclusions of the Commissioners are equally relevant to Armstrong's contribution to education and science. Not only do they show that technical schools were increasingly making their courses more appropriate to the needs of industry but that, almost forty years after

Windlow's class began at Elswick, employers were, at last, realising the need for such education in their fight to win orders against foreign competition. (Samuelson Report, Conclusions Part IV, pp. 513- 514).

One conclusion is worth quoting in full, since it might supply an answer to the enigma of Armstrong:

> 'The Englishman is accustomed to seek for an immediate return, and has yet to learn that an extended and systematic education, up to and including, the methods of original research, is now a necessary preliminary to the fullest development of industry. It is, amongst other elements of progress, to the gradual but sure growth of public opinion in this direction, that your Commissioners look for the means of securing to this country in the future, as in the past, the highest position as an industrial nation'. (Samuelson Report, Conclusions Part IV, p. 525).

Armstrong's single minded purpose towards Elswick and its best interests has been an ever recurring theme in this study. Mindful of that and of the Commissioners' conclusions regarding 'extended and systematic education, original research, and the fullest development of industry', the question now arises: 'Is this why, after so many years of apparent instransigence, Armstrong, at last, gave his unequivocal support to the College of Physical Science in Newcastle?' The trauma of justifying his vision of modern ordnance before reactionary committees, in the 1860s, and of his resultant decision to 'go it alone' thereafter, were over. Elswick had now been nationally recognised, not only as an industrial complex, but as a centre of excellence for scientific and technical education. Equally, in the upper echelons of scientific research, the College of Physical Science, combined as it now was, with all the facilities of Durham University, had much to offer Elswick. Once again, the way was open for an exciting new development, and, as usual, he was equal to the challenge. Henceforth, through premium apprenticeships and scholarships to the College which was to bear their founder's name, the young engineers from Elswick had every opportunity to achieve graduate status and, in may cases, international renown. Through Armstrong's vision and encouragement, their educational opportunities now seemed limitless, compared with those pioneers who met in Windlow's humble cottage, for 'the purpose of mutual instruction'.

Although Armstrong did not give evidence before the Samuelson Commission, his commitment to technical education had not waned. Indeed, he was increasingly recognised as an expert in this field. This is evident when he became involved in the work of the City and Guilds in its early days. According to the Samuelson Commission, 'the City and Guilds of London Institute owes its existence to the conviction of the liverymen that technical instruction is a necessary condition of the welfare of our industries'. (Samuelson Report, Conclusions Part IV, pp 513-514).

As the demand for technical education grew, so did the proliferation of examinations set by the Science and Art Department and the Society of Arts. In consequence, much of the work was being duplicated. Partly because of their vast financial resources and partly because of their obvious vested interest in technical education, the Livery Companies of the City of London became involved. Moreover, as the evidence of the two Royal Commissions has shown, the place of workshop practice in technical education caused dissent as well as discussion. Both Armstrong and Bell agreed that it could not be taught in a classroom, but until the men of theory could work amicably with the men of practice, no satisfactory system of technical education could be devised. Few technical institutions had the contiguous industrial facilities of Elswick, thus, Armstrong seemed a logical choice when a group of eminent persons were asked to give their views.

Lieut Col. J.F.D. Donnelly, R.E., one of the main exponents of technical education, was among the leaders of the campaign, which has been acknowledged in recent times as 'the most adventurous attempt of the nineteenth century to provide a comprehensive course of practical technical education for engineers'. (F.E. Foden, "The Rev. Arthur Rigg: Pioneer of Workshop Practice", Vocational Aspect, Vol XI, No 23, 1959, p. 105). The Livery Companies set up a working group to prepare a feasibility study on the matter. They prepared their recommendations after obtaining 'from men of high standing and of varied pursuits their views upon Technical Education'. On 28th July 1877 they sent a letter to 'a number of gentlemen whom they had selected on account of their knowledge of pure Science, their acquaintance with Scientific education and with Technical Examination (sic) , their position as employers of labour, or by reason of other qualifications rendering them competent to give valuable advice'. ("Technical Education", Report of the Committee of the Livery Companies of London, 1878, p. 1).

With the inducement of £100 honorarium, which was refused in most cases, Armstrong, Professor Huxley and Donnelly were among the six respondents. When the reports were collated, the working group recalled that: 'The object of the Livery Companies was the improvement of the technical knowledge of those engaged in the manufactures of this country, whether employed as workmen, managers or foremen, or as principals'. The working group agreeing, by implication, with Armstrong's stated views before the Devonshire Commission, argued that: 'It would be unwise to establish any place for teaching the actual carrying out of the different trades (like) a model manufactory or workshop', although technical education should 'give those employed in manufactures the knowledge of Scientific or Artistic principles upon which the particular manufacturer may depend'. (Livery Companies' Committee Report, p. 2).

In the event of their advice being accepted, they urged the General Committee to take cognisance of 'the advice so strongly given by Sir William Armstrong and others to proceed by steps and not to commence upon an extravagant scale'. Armstrong's experience with the College of Physical Science is evident in the working group's proposal that custom built institutions were not an immediate priority since educational success depended on 'the energy and ability of the professors and others concerned in its management and not upon the character of the buildings'. On the other hand, they envisaged the eventual erection of a purpose built college with appropriate 'apparatus, laboratories, and other accommodation'. (Livery Companies' Committee Report, pp 3-5).

In a letter from Newcastle dated 31st October 1877 Armstrong gave his report on technical education. (See Appendix IX). By this time, his educational work at Elswick had been assessed by two Royal Commissions and had won national approval, while his own views on technical education had often been publicly expressed. Despite his visionary outlook, often stamping him as a man of the twentieth century, how far was he still a man of his own time, with all the limitations of the self made man of the Industrial Revolution? In this respect, how far did Armstrong accord with Hans' view which, as noted earlier in the context of Eldon, suggested that, having risen themselves, the new industrial middle class tried to prevent others from doing likewise. (Hans, 1950, p. 211). Armstrong's letter to the Livery Companies may provide some of the answers.

In line with the men of the early Industrial Revolution, Armstrong's fame had been achieved only through single minded dedication and sheer hard work. His young team of managers and ambitious workmen were cast in the same mould. His was no broad educational highway, envisaged by social reformers, but a narrow hard road for an intellectual and scientific élite. Nevertheless, for those who accepted the challenge, irrespective of social origin, he was prepared to provide the best educational and industrial facilities available. In the final analysis, Armstrong was too shrewd a business man to fit neatly into Hans' assessment of the archetypal industrialist. He knew too well that Elswick's best interests were not being served by emulating earlier industrial practices where 'the opportunity for education and consequent social rise was actually non-existent and the long hours and drudgery of the factory killed all initiative'. (Hans, p. 211). When arguing his case, the trained lawyer and the experienced business man was extremely clever at negotiation. He conceded nothing, yet, he knew how far to go to achieve the most favourable result - favourable invariably for Elswick; favourable always for Armstrong.

His philosophy for education can be seen most readily in the final paragraph of the letter to the Livery Companies: "Although I have treated education in science from a purely economic point of view. I must not be deemed insensible to its claims as a means of intellectual culture; but arguments in its favour based on utility are quite sufficiently strong to render superfluous those which rest upon sentiment". (See Appendix IX).

Meanwhile, on what evidence did Huxley base his argument, noted above, that: 'They have one of the best elementary scientific schools extant in Elswick'? (Samuelson Report, paragraph 3000). Praise of that order, from one of Huxley's academic prowess, before a Royal Commission, is worthy of more than a passing reference. Equally noteworthy is the fact that when the Commissioners circularised the manufacturers on the subject of technial education, they considered the full and detailed information from Elswick as being among 'the more important replies'. (See Appendix VIII).

The Elswick Schools Log Books show that Science was an essential part of the curriculum for both boys and girls and that the older pupils were encouraged to avail themselves of the facilities offered by the Mechanics' Institute.

As the Works continued to expand and diversify, first into ordnance - both land-based and maritime - then into shipbuilding, Armstrong became increasingly aware of the need for scientific education for his employees. Equally, his more ambitious workmen, in turn, supported his educational initiatives at Elswick. The impetus thus given, especially to the work of the Institute, necessitated the appointment of a professional educationist to have overall supervision of the classes. In view of the criticism levelled by the Devonshire Commission at the standard of Science teaching in the country as a whole it is appropriate to study, in some detail, the career of the man whom Armstrong first appointed to this post. Indeed, the fact that such an appointment was made a year before the Devonshire Commission began its deliberations shows the importance of Science teaching in Armstrong's own mind, and in his scheme for Elswick.

Born in 1839, William Thomas Rowden became a student in the School of Mines. (Devonshire Report, paragraph 2302). Thereafter he became an 'apprentice teacher' at Abbot's Ann School in Hampshire, in 1852, before training for his certificate at Winchester in 1858. From 1859 - 1869 he taught at the Bristol Trade and Mining School at Woolwich Arsenal and at Clifton College, Bristol, where he lectured in Science. Although no evidence has been found to substantiate the claim, it is possible that he became acquainted with Armstrong during the latter's own time at Woolwich. In 1869, he became both Science master at the Elswick Institute and Organising tutor for the Northumberland and Durham Coal Trades' Association for Technical Education. He held the former position for nine years and the latter for two. (E.W.L.M.I. Papers).

Further evidence of Rowden's academic acumen is seen in the fact that he left Elswick, in 1876, to become the first Professor of Applied Mechanics at the Andersonian Institute, in Glasgow, now the University of Strathclyde. Such was the calibre of the man whom Armstrong appointed and whose work, along with that of his immediate successor, was to win for Elswick the recognition of two Royal Commissions.

W.W. Smyth, Professor of Mining at the School of Mines, in his evidence before the Devonshire Commission, spoke of Rowden in the context of the educational developments at Elswick and its vicinity:

> 'At Newcastle, an attempt has been made quite recently to get up classes which should be in connection with the South Kensington examinations and which should be accessible to young men at Hetton and Elswick and many other places in the neighbourhood of Newcastle; but in consequence of an alteration in the South Kensington arrangements for payments, the committee of the Mining Institute of the North of England, who have taken it into their charge, are very much afraid that the whole will break down. They have succeeded in the course of two years, during which they engaged one of our former pupils, Mr. Rowden, to be teacher, in educating to a certain point, that is to say, in teaching several hundred students; but they say at the present moment that they are rather doubtful about ultimate success from want of funds. The chief reason, I believe is, that a teacher can with greater facility get together large classes and make a good income out of them, by remaining in the large towns, whilst he finds that his visits to those actual centres of mining operations are coupled with too much expense to allow them to be remunerative'. (<u>Devonshire Report</u>, paragraph 2302).

Rowden's successors were cast in a similar mould. First came Mr (later Dr) D. Evers who held the post for fourteen years. Remarkably, the E.W.L.M.I. Papers refer, unfailingly, to <u>Mr</u> Evers, yet the official communication from Elswick to the Samuelson Commission names him as <u>Dr</u> Evers on more than one occasion. (<u>Samuelson Report</u>, Vol XXXI,

Appendix G, p. 649). Assuming such high academic qualifications, it is not surprising that he enlisted Armstrong's help in building a Chemistry laboratory adjacent to the Institute, on land given by the Company. This, as noted earlier, was considered to be the largest and most efficient of its kind in the North of England. Evers' views were in line with those of Armstrong who, during the subsequent debate with Playfair on technical education, still argued the case for increased laboratory facilities. In Armstrong's view, such facilities should give greater opportunity for experimentation and in the use of scientific apparatus. These were essential to counteract the customary book learning and class questioning criticised by the Royal Commission on Scientific Instruction. (Devonshire Report, paragraph 76).

In 1890, Dr Evers was succeeded at Elswick by Mr Robert Wills, a graduate engineer, who died in office in 1912. Although this was after Armstrong's death, it is interesting to note that the high standards he laid down were still being maintained at Elswick. Evidence of this is seen when the appointing Committee recorded the 'need to find a worthy successor'. (E.W.L.M.I. Papers). They did so in Mr Charles E. Handy, a Whitworth Scholar who was an Associate Member of both the Royal College of Science and of the Institute of Mechanical Engineers. He epitomised the combination of theory and practice so beloved by Armstrong and endorsed by the Royal Commission on Technical Instruction. Not only was he a precision engineer, but he had had a 'thorough training in the Workshops and Drawing Offices of the Royal Dockyards at Devonport'. (E.W.L.M.I. Papers). Although such experience would be invaluable to Elswick at that time, he was destined to remain in office for only three years, until the closure of the Day Science Classes, during the First World War.

The commitment of these men in the sphere of education at Elswick is on a par with that already noted in the firm's engineering departments. A salient factor in both contexts was Armstrong's ability to choose the right men for the task in hand. This was acknowledged in one of the Institute's Reports some years after his death:

'Many tributes have been paid to the outstanding genius of the first Lord Armstrong. His mechanical inventions largely moulded the life of the present industrial world. In no sphere was his genius more evident than in his faculty of selecting men capable of translating his ideas into practical form. He surrounded himself with such men and his strong social instincts ever sought their better welfare. His selections in many instances were extremely happy ones'. (E.W.L.M.I. Annual Report, 1933, in E.W.L.M.I. Papers).

Meanwhile, under the supervision of Mr Wills a Day Science class was started, in 1891, for boys who had passed Standard VI in the elementary school. This class eventually developed into a Day Technical School under later Government legislation and, by receiving Government recognition, it qualified for grants. Girls were also admitted to the school whose history spanned a quarter of a century.

The Day Science Classes (later the Day Technical School), were the third pioneer movement in the educational initiatives at Elswick undertaken by Armstrong and loyally supported by his employees:-

1. The Institute Classes established in 1848
2. The Day Elementary Schools established in 1866
3. The Day Science Classes, established in 1891.

Each of these undertakings was functioning satisfactorily years before the Government attempted to provide similar resources for the general public. Nonetheless, when Parliament began to assume responsibility for technical education, the ensuing legislation had important consequences for Elswick. The Local Government Act of 1888, which established County Councils, outlined specific areas of responsibility within the jurisdiction of the local authority including that of technical education. The following year, the Technical Instruction Act empowered the local authorities to levy a penny rate for technical education. These rates were further aided by grants from the Science and Art Department as well as through the Local Taxation (Customs and Excise) Act of 1890, when the so-called 'Whiskey Money' was made available to the County Councils for a variety of purposes, including technical education. An enabling Act was also passed to allow the County Councils to provide scholarships for such education. These various functions were administered by the local Technical Education Committees. In this context, it is relevant to note that the Committee of the Day Science and Art Classes at Elswick were nominated the 'Local Committee for the Benwell District for the establishment and supervision of Evening Continuation Schools and Technical Education Classes under the County Council of Northumberland Technical Education Committee'. (E.W.L.M.I. Annual Report 1899, in E.W.L.M.I. Papers).

Through the new legislation, the Science and Art Department appeared to be gaining much greater control of technical education than the Education Department. Partly as a result of the recommendations of the Cross Commission in 1888, the Education Act of 1889 created the Board of Education, which became the central authority assuming the responsibilities formerly vested in the Charity Commissioners and the Science and Art Department.

As Cardwell noted: 'The battle for State-aided technical education had been won; ----- the scene was now quite modern with polytechnics and technical colleges; ----- the Mechanics' Institutes were no longer a living issue'. (Cardwell p. 160).

Thus, it is against this national scene that the next stage of

Elswick's history must be considered. The Institute classes from 1869 under Rowden and the Day Science Classes from 1891 under Wills could be seen as being of post-elementary standard. Thus, by comparing their work with that prevailing elsewhere the question arises: 'How far was Armstrong in advance of his time by making such provision at Elswick?'

Opportunities for post elementary education became an important issue after the passing of the 1870 Education Act. Such opportunities presented themselves mainly through evening classes or through a higher stage within the elementary system and, occasionally, through scholarships to grammar schools. This was the so called 'educational ladder' by means of which children from modest homes could aspire to higher positions and even to university education. The more entrenched members of society - including many churchmen and members of School Boards - were opposed to the provision of such post elementary education, either from public funds or private agencies. In London, such opposition prevented the establishment of higher grade schools until the 1890s. (Lawson and Silver, p. 337).

Nonetheless, there were those who saw the need for greater social justice through improved educational provision. In view of Huxley's admiration of Elswick, it is interesting to note that he was among those who deplored the waste of talent among the lower classes through inadequate schooling. Thus, his admiration of Armstrong's educational initiative at Elswick can be set in context.

Within a decade of the passing of the Education Act of 1870, there was a demand in the North of England for schools which, catering for the needs of working class children, would offer a higher form of education than that obtainable in the ordinary elementary school. (R.L. Morant, First Memorandum, 1897, revised 1901. "The Higher Grade

Schools in England, their origin, growth and present condition". Quoted in E. Eaglesham, From School Board to Local Authority, 1956, Appendix A, p. 184).

By 1879, permission to establish higher grade schools was already being sought at Sheffield, Barrow, Bradford, Nottingham and Halifax. The publication, in 1884, of the Report of the Royal Commission on Technical Instruction, led to an even greater demand for the establishment of Schools of Science. (Morant, First Memo, quoted in Eaglesham, 1956, p. 187). Gateshead was among several Northern towns which led the second wave of higher grade schools in the mid 1880s and it is noteworthy that Mark Wright, who has already been named in the context of the Day Training College in Newcastle, went there as Principal after being Headmaster of the Gateshead Higher Grade School from its opening in 1884. (Tyson and Tuck, p. 20). Meanwhile, in the absence of any similar initiative in Newcastle, at this stage, the unique facilities at Elswick assumed an even greater importance.

For example, the curriculum in the London Higher Grade Schools bears interesting comparison with that being offerred at Elswick at the same time. The former has been described as: 'scientific, literary and commercial. In the literary direction, some language besides English is taught in every higher grade school. A systematic course of study in the upper grades of schools including such subjects as physics, chemistry, mechanics, machine drawing and mathematics encouraged their introduction in the lower standards and in the higher grade schools the curriculum, however broad, generally placed strong emphasis on scientific and practical subjects'. (Lawson and Silver, p. 338).

Before Armstrong's death, the examinations of the Science and Art Department were being held at Elswick in the following subjects:

Mathematics, Mechanics (theoretical and applied), plane and solid Geometry, Machine Construction, Magnetism and Electricity, Sound, Light and Heat, Physiography, Chemistry, (theoretical and applied), and freehand, model and perspective Drawing. At the same time, Elswick students were being trained for commerce as well as industry, because classes in French and Shorthand were reported as producing 'most gratifying results'. (E.W.L.M.I. Annual Report 1891, in E.W.L.M.I. Papers).

Although the higher grade schools occasionally acted as stepping stones to the grammar school and university, they were usually seen as giving access to skilled and clerical occupations. It was argued that neither the higher grade schools nor the 'scholarship ladder' to the grammar schools was really catering for the children of the poor, but for a slightly higher class in the elementary system. These included the 'labour aristocracy' who were the better paid 'upper strata' of the working class and whose social position was often similar to that of the lower middle class. (Lawson and Silver, p. 338). These findings are certainly in line with Armstrong's provision at Elswick for his own 'labour aristocracy' who had the will and motivation to benefit from it. Moreover, it will be seen later that Elswick offered its young engineers scholarships tenable at various universities. Thus, within the limits of engineering and science, it could be argued that the facilities at Elswick were a cross between a higher grade school and a grammar school.

The Day Science School, begun in 1891, gave a general education to boys and girls between the ages of 12 and 16. Although no specific trade instruction was given, the majority of the boys were later employed at Elswick Works. The curriculum included English, Mathematics, Science, Drawing, History and Geography. The fees were 3 pence a week or 3 shillings a term for the children of those Elswick employees who subscribed to the Mechanics' Institute funds, or double that amount for the remainder. (Board of Education <u>Report on the ELSWICK INSTITUTE</u> for the period ending on 31st July 1914 in E.W.L.M.I. Papers).

Despite the high standard of work which earned Elswick several favourable reports, a decrease both in the overall membership of the Institute and in the Day Science and Art classes was noted for the years 1893-1896. No reason for the decline appears in the Reports but contemporary educational developments in Newcastle are noteworthy since they could have been a contributory factor. Dr J.H. Rutherford, a pioneer of free secondary and technical education had opened a Science and Art School in the west end of the city in 1879. (Middlebrook, 1968, p. 292). Despite additional laboratories, workshops and Art rooms, the facilities were still inadequate and a new building was started in 1890, shortly before Rutherford's death. The completed building, which was opened in 1894 by the future King George V, was known thereafter as the Rutherford Memorial College and, even during Armstrong's lifetime, offered courses similar to those at Elswick.

The importance of Rutherford's work in the context of Armstrong, can also be gleaned from an observation by Middlebrook: 'For a whole generation before the First World War, the four dominant figures in the intellectual life of Newcastle were Lord Armstrong, Alderman Joseph Cowan, Dr J.H. Rutherford and Dr Robert Spence Watson, there being hardly a single activity in the city with which one or another of the four was not prominently connected'. (Middlebrook, 1968, p. 310).

Although Armstrong died in December 1900, it is appropriate to consider the later history of the Schools up to their closure in 1916. This is relevant to the present study, not only because it shows important educational developments in the vicinity of Elswick, but it reveals just how far Armstrong was in advance of the educational thinking of his day and how far Samuelson's faith in Elswick was justified.

Although the Day Science School had a very satisfactory career under the direction of Mr Wills, by 1912 the Institute Committee seemed less than complacent about the number of pupils in attendance. The Annual Report of that year drew the attention of the parents 'to the special facilities that these classes offer for boys who intend entering the Works as apprentices'. They emphasised that the syllabus had been prepared with that in view and drew attention to the fact that on completion of two years at the Day Science Classes, students could enrol for evening Science and Art classes without attending the Evening Preparatory Class at the Institute. (E.W.L.M.I. Annual Report 1912, in E.W.L.M.I. Papers). As a result, 78 pupils enrolled in 1913 as against 52 the previous year.

Meanwhile, the Board of Education had issued new Regulations for Junior Technical Schools, and in 1913, the Committee at Elswick modified their curriculum accordingly and applied to the Board for official recognition under this scheme.

Unfortunately, the Headmaster, Mr Wills died at the beginning of the 1912-1913 session, and his post was not filled for the remainder of that academic year. Thus his successor, Mr Charles Handy, despite excellent qualifications in both engineering and technical education, had a difficult task to perform. During his first year in office, Her Majesty's Inspectors paid an official visit. They paid tribute to Mr Handy's work and to the achievements of the Science, Mathematics and Art classes. Nonetheless, they criticised the lack of recreational facilities for growing children afforded by the Institute premises and the narrowness of the liberal aspects of the curriculum. In their concluding remarks the Inspectors praised the School's 'long record of useful work when, in years past, it occupied something of the position of a pioneer'. They were confident that any 'deficiencies could be easily overcome and that the school was capable of playing a most useful part in the technical education of embryo mechanics and draughtsmen'. They further suggested that: 'the key to the future lies with the great firm of engineers with whose work the school is so closely associated'. (Board of Education Report on the ELSWICK INSTITUTE for the period ending on 31st July 1914).

Unfortunately for the School's future, Armstrong was dead and, despite the genuine commitment of his successors, world events were clouding the horizon. With the outbreak of war in 1914, the Elswick premises - the Institute, Elementary Schools and Works - were placed on a war-time footing with troops occupying the Schools. Under these circumstances, the Company was not prepared to concede to the Board of Education's demands and the Day Science and Art Classes closed in 1916, while the elementary schools never again re-opened after being commandeered by the Army.

Another factor contributing to the demise of the Day Science School could have been the opening, in 1910, by Newcastle Education Committee of a higher elementary school for boys and girls in nearby Atkinson Road, which later became a technical school and offered courses similar to those at Elswick, but in modern, custom built premises.

Nonetheless, during the Firm's prosperous years and the consequent growth in the numbers of employees, the number of students attending the Institute increased accordingly. When the existing buildings proved to be inadequate, the Firm agreed to enlarge the premises. (E.W.L.M.I. Annual Report, 1898, in E.W.L.M.I. Papers). In the event, it was not until two years after Armstrong's death, that the Company were able to erect and equip 'commodious buildings' behind the elementary schools. In the ensuing years, the Institute achieved the maximum of its activities and usefulness. As many as 600 to 700 students enrolled for each session and attended their various classes week by week, as Armstrong had envisaged. Examinations were held under the auspices of the Board of Education, the Society of Arts and the City and Guilds of London Institute. The results were of a high order and included the award of Whitworth Scholarships and Exhibitions, National Scholarships and Engineering Scholarships awarded by the Company tenable at the Durham College of Science. Formerly the College of Physical Science it became known, in 1904, as Armstrong College in honour of the founder of Elswick. Although the National and Whitworth awards had their own regulations and were tenable at colleges throughout the country, the Company's Engineering Scholarships were available to apprentices of Elswick or to the sons of employees, on condition that the holder returned to the Company on graduation. It was a further generous condition that the scholarship winners could supplement their college training by continuing their workshop practice in the Elswick Works during the vacations. Thus, by combining university theory and workshop practice, a new dimension was added to Armstrong's vision of Elswick as a centre of academic and engineering excellence.

Again, by encouraging potential scholarship winners, Elswick was not only supporting Huxley's views by enhancing the educational opportunities of working class children, but was in line with the general recommendations of the Samuelson Commission:

'That scholarships be more liberally founded especially for pupils of higher elementary schools, enabling them to proceed to higher technical schools and colleges'. (Samuelson Repbrt, Vol. XXIX p. 539 Item III).

What did the Institute, the Schools and the Day Science Classes achieve in Armstrong's lifetime? How far were the two Royal Commissions (Devonshire and Samuelson) justified in acknowledging those achievements?

One of the Institute's own reports, written at the height of the Great Depression which had such dire consequences for the Elswick Firm, gives some insight:

'The Elswick Institute has been for over 85 years a great centre of intellectual and social activities for the employees of the Elswick and Scotswood Works. Its educational value can never be measured nor told. It stands as a very great credit to the workers and, in a pronounced sense, the expression of their own mental alertness and solicitous ambition for the welfare and uplift of their fellows. Its sons have gone into many parts of the world, carrying with them its shaping and creating power on their lives, enabling them to ennoble and enrich others wherever they go'. (E.W.L.M.I. Annual Report, 1933, in E.W.L.M.I. Papers).

CHAPTER XV.

THE SCIENTIFIC AND TECHNICAL DEBATE.

PLAYFAIR VERSUS ARMSTRONG.

As head of one of the country's leading industrial enterprises; as the acknowleded expert in hydraulics; as a pioneer in electrical research; as the respected president of learned societies, Armstrong's responsibilities and concerns were extensive in the extreme. By contrast, men like Playfair, involved as they were in a single enterprise, could concentrate on the scientific and technical debate and be given full credit for their deliberations yet Armstrong, in his capacity as one of the country's leading engineers, was heeded mainly by men of similar interests, while his views on education were lost among the wider issues of his prerorations. Nonetheless, his speeches, when read in detail, contribute as much to the furtherance of education as they do to engineering, and should be considered in that context.

The developments in scientific and technical education in the later years of the nineteenth century caused Armstrong to break with his usual practice and express his views in print. In doing so, he found himself at variance with Playfair. In an article written in July 1888, by which time he had been elevated to the Peerage, he outlined the recent developments in technical education and noted that opinions differed on the precise meaning of the term; on the class of person most suited to benefit from it; and on the ages for which it should be provided.

He claimed that the proposals for establishing polytechnic institutes in London made it "a fitting time for bringing forward ideas which have long been incubating in my mind, and which, I believe, are in accord with those of many employers of labour who, like myself, are engaged in manufacturing pursuits in which technical requirements afford most scope for application." (Lord Armstrong, "The Vague Cry For Technical Education", The Nineteenth Century, Vol. XXIV, No. 137, July 1888, p. 45). In the last sentence, Armstrong revealed the real reason for his interest in technical and further education. It was as an employer, rather than as a social reformer that he became involved. Thus, it becomes evident that the young lawyer, newly returned from London in 1833, found Greenhow's proposed College in Newcastle an irrelevance. Only now, as a Peer of the Realm, as well as a Captain of Industry, was he unequivocally committed to the cause, even though he still had certain reservations on its implementation.

Armstrong first looked at elementary education "which is now very generally considered to be ill adapted for the business of life". In his opinion the system merely instructed rather than developed the intellect. "A man's success in life," he argued, "depends incomparably more upon his capacities for useful action than upon his acquirements in knowledge which may be deferred to a more mature age". He further argued for the education of the whole man when he suggested that the body should be trained as well as the mind. Physical exercises were important, since personal vigour and activity were vital factors in earning a living. In making this remark, how far was Armstrong being objective or how far was he speaking with the self-interest of the employer?

Apart from teaching art, which, he claimed, was "as a rule, very imperfectly done in elementary schools", little was being done to educate the hand. Dexterity in the use of simple tools, he felt, would be a useful accomplishment for the future. Nonetheless, he was quick to condemn the teaching of special trades or manufacturing processes to children, since this would "only forestall the more effective teaching which at a more suitable age may be attained by actual practice in factories and workshops". (Armstrong, "Vague Cry", p. 46).

On the question of training the mind, he considered that, although learning arithmetic was an advantage, it should be done by reasoning and not by rote. "A rule", he claimed, "may be committed to memory for convenience of use, but the first object should be to make the learners understand, as far as possible, the reasons upon which the rule is founded". He then criticised the present system for doing little more than cramming the memory with information rather than developing the intellect or preparing it to meet the challenges of working life. He argued that current methods of instruction evoked little interest in the pupils, who soon forgot the lessons so laboriously taught.

Again, the arguments of the employer can be heard in his assumption that even where children are sucessful in learning by this method "the effects are by no means beneficial" since their apparent superiority "makes them scorn manual labour. Successful boys prefer being teachers or clerks instead of mechanics while girls shun domestic service to become shopwomen, milliners, telegraph operators and so forth". (Armstrong, "Vague Cry", p. 47). The elementary school curriculum, he claimed, should include reading, writing, arithmetic and drawing, because, like general knowledge, they were appropriate to the needs of adult life. Juvenile lectures on experimental science, followed by simple examinations, would not only interest the pupils but develop habits of observation and reflection which would be of permanent benefit.

He agreed with Professor Huxley's views that the present system of education was too bookish. In his opinion, such teaching should be reduced, and replaced with mental and physical training. In developing such he claimed that children often learn more from their own games than from their teachers' lessons. Moreover, in words reminiscent of Froebel's theories, he stated his own beliefs that "training associated with amusement might be so systemised as to produce excellent results, both in mental and bodily development, as well as in the promotion of health and vigour". Again, in words which were to be echoed on Tyneside and other 'inner city' areas down to the present day, he argued that to achieve such development, "a sufficiency of food and clothing is especially necessary. Indeed, the want of it in the children of poverty-stricken parents is already a serious difficulty in popular education". (Armstrong, "Vague Cry", p.48).

The question of self-help, the corner-stone of Armstrong's debate, then engaged his attention. He argued that: "It must be conceded that where a man fails to get on in the world, it is not from want of knowledge, so much as from want of natural capacity, and of zeal, energy and perseverance. If he possesses natural capacity, combined with these qualities, he will not suffer himself to be defeated by want of knowledge, but will surmount all difficulties in attaining it". He then argued that he had never met capable men who were unable to find the knowledge necessary for their advancement, although there were those who argued that genius is kept down from want of knowledge, and that in many cases it was thus lost to the world. This he entirely refuted on the grounds that genius was irrepressible and those who possessed it enjoyed the challenge of difficulties. Apart from members of the learned professions, he continued, few distinguished men owed their success to book learning acquired in early life. Naturally, he cited the examples of the well known engineers who, with little or no schooling, "were left to educate themselves in after life, with scant facilities, in such knowledge as was necessary to the attainments of their ends". Indeed, he maintained that it was their very paucity of book learning that enabled the early engineers to concentrate on the most essential skills and bring them to perfection.

As with engineers, so with our national heroes. Marlborough, Nelson and Wellington, he claimed, would never have led their men to victory "if book knowledge had been crammed into them at school". Then, raising a subject to which he was later to return with some force, he argued that these men's services would never have been at their country's disposal "if success in competitive examinations, such as are now in vogue, had been made a condition of their entering the army or the navy". (Armstrong, "Vague Cry", p. 49).

His debate then moved to technical education and the type of person most suited thereto. He refuted the popular notion that the working classes were those who would benefit most. Taking the example of the labourers classified as 'the hewers of wood and the drawers of water', he maintained that no improved technical knowledge would make them more efficient at their particular job, although the value of their labour would increase if, as boys, they had been trained to use their hands and limbs. Even skilled workmen, he claimed, depended more on the intelligent use of manual skill than on knowledge. By contrast, the foremen who were chosen as much for their intelligence as their skill, were the first group to emerge from the ranks of the working classes. Thus it was towards them that the benefits of technical education should be directed. Even so such knowledge as they required was easily attainable in tabulated form from books applicable to their particular trades. "Such technical information", he argued, "is in this form available to every man who can read and do arithmetic, however ignorant he may be of the scientific methods by which the results have been arrived at". (Armstrong, "Vague Cry", p. 50). Whereas a knowledge of simple algebra and geometry would be conducive to greater understanding, he maintained that such limited accomplishments could easily be acquired by private study. Indeed men of this calibre often resorted to self help, rather than to formal education, to enhance their career prospects.

The next class under consideration was that of managers and designers who "require technical education in a higher degree". Even here, he considered that: "It is only in pursuit of research and discovery that highly advanced scientific knowledge is required and not even then in all branches of science". On the whole, he persisted, the number of people who would actually benefit from "scientific education of a technical nature", and who had the motivation for its achievement, was so limited as to call into question the need for further provision.

He then outlined the existing facilities, beginning with those in large towns where evening classes were conducted under Government regulations for the teaching of practical and applied science. Here, of course, he had the example of his own Mechanics' Institute at Elswick. If the demand for subjects like bookkeeping and shorthand was sufficient, he claimed, these subjects could be taught in a similar manner. Perhaps with the example of the literary and philosophical institutions in mind, he recalled that there were a number of associations of a general scientific nature which afforded opportunities for self education, by means of lectures and discussion groups. Associations like these could be increased, although he believed that they were keeping pace with demand. Additionally, he noted, people had the advantage of university extension lectures, as well as having "access to the abundance of libraries, either absolutely free or belonging to mechanics' institutes or scientific societies, to which anyone can be admitted on payment of a very small annual subscription". Moreover, there was an abundance of cheap scientific literature including reference books of a technical nature "applicable to almost every kind of employment on which science can be brought to bear". (Armstrong, "Vague Cry", p. 51). Despite such provision, he argued that there was still a deficiency in the supply of laboratories and a dearth of classrooms for evening teaching.

He then made reference to the colleges of physical science which, he argued, were "apt to be too scholastic for popular requirements". Although conceding that they performed a useful function in the cultivation of abstract theoretical science, as well as for the education of teachers of science, nonetheless, he felt that these colleges should include more practical instruction although it was available elsewhere at less cost. His commitment to the voluntary principle as well as his experience of the College of Physical Science in Newcastle can be seen in his next statement. Where colleges are established by public subscription or private benefaction, he claimed, they are "worthy of approval and commendation". By contrast, where the State or local authorities have to provide money for education relating to national industry, he claimed, "they must look to attaining the required results at the least possible expense, and I am inclined to look upon colleges as luxuries in education rather than as necessaries". (Armstrong, "Vague Cry", p. 51).

Unfortunately, the facilities he mentioned were found only in large towns so he suggested that the smaller towns and rural areas should enjoy comparable amenities which were geared to local needs. Even in rural districts, where the chief occupation was agriculture, he argued that "great ignorance prevails in the practice of this important industry". Nonetheless, "there does not appear to be much desire for enlightenment amongst the farming population, for in the few cases where night schools have been established for useful instruction relative to farming, the attendance has been very unsatisfactory". (Armstrong, "Vague Cry", p.51).

In an observation with modern connotations, he noted the problem of foreign competition. Pondering whether increased technical knowledge would safeguard our commerce from such incursions, he declared that he had strong reservations in the matter. In the last resort, he argued, the case would be decided on cheapness of production and superiority of quality. Thus, it was necessary to educate our people accordingly, if we were to retain the foremost place. Although he did not undervalue "technical knowledge voluntarily acquired as a means to an end", he argued that the brain workers, rather than the manual workers, would seek to attain it and benefit thereby. Compulsory education, he emphasised, was justifiable only in childhood. Yet, without such a spur, only those of superior intellect, high motivation and business initiative would avail themselves of the emerging educational facilities. Any further provision should await demand and be supplied only "gradually and tentatively". It would be folly, he claimed, to embark on new and costly schemes without being certain that they would bring beneficial results. (Armstrong, "Vague Cry", p. 52). Again, perhaps in a reference to Elswick, he agreed with Professor Huxley's approbation of the work of the Science and Art Department in promoting evening classes for the teaching of art and practical science. Nonetheless, he argued that if Government intervention were required in other branches of technical education, the provision should be extended along similar economical lines.

His summary showed that he was presenting his case for popular education strictly on utilitarian grounds. His topic was technical education, therefore he had completely ignored questions of a religious or moral nature. "Happily", he concurred, "those subjects are now treated in a much more conciliatory spirit than formerly, and I hope that any remaining impediments to popular education of an elevating kind may eventually disappear". (Armstrong, "Vague Cry", p. 52).

Naturally, such radical views could not go unchallenged and Playfair led the attack. Writing only two months later, in the same magazine, he overturned Armstrong's arguments. Nonetheless, in view of Armstrong's high scientific and industrial reputation, Playfair's criticism seems to have been made more in sorrow than in anger. According to him, the 'douche of cold water' thrown by Armstrong 'on the warm efforts which are now being made to promote technical education' was 'a serious discouragemant coming from a man of his eminence as a great manufacturer and a lover of science'. As such, Playfair felt, 'he has an undoubted right to be heard and it is the duty of someone who is interested in technical education to reply to his article'. (Lyon Playfair, "Lord Armstrong and Technical Education", The Nineteenth Century, Vol. XXIV, No. 139, September 1888, p. 325).

He then acknowledged the remarkable amount of common ground between Armstrong and the promoters of technical education. All agreed that the primary schools did not adequately train the faculties of the working classes and that the curriculum should be less bookish and more objective. Where, asked Playfair, did Armstrong's aspirations differ from the rest? His aim to 'train the eye and hand to be more efficient instruments of the mind' was echoed not only by individual promoters of technical education, but by the recent Bills introduced into Parliament. If the main object of technical education is 'to teach working men to observe, to appreciate and to think', Playfair argued, such education 'should begin in the kindergarten and end in the college'. Nor in secondary education could Playfair identify points of divergence between Armstrong and the rest. Indeed, he averred, Armstrong's views were such that not only should he have been a member of the Technical Association, but he had little apparent motive for writing such a critical article in the first instance. The promoters of technical education had long been striving towards the ideals suggested by Armstrong, thus, Playfair maintained, he should have applauded, not condemned their efforts, when the cause was gathering momentum.

What did Armstrong fear? Did he think that the school would supersede the workshop? His own experience in Newcastle, which, in a later article, he used to support his argument, was a case in point. Certainly Playfair could find no cause for any doubts. He, personally, had 'laboured to promote technical education for fifty years and had constantly opposed even the introduction of any kind of actual training in industries into our schools and colleges'. (Playfair, "Lord Armstrong", p. 326).

Playfair agreed in principle with Armstrong's main argument that the greatest discoveries of the age were made by men of natural genius, devoid of technical education. Even so, he argued that the majority of men now in responsible positions were not in that category and it was to them that such provision must be directed. He then argued that such education should 'give an intelligent knowledge of the sciences and arts which lie at the basis of all industries'. Moreover it should be given in early life, before the youth began his practical training in the workshop.

(Playfair, "Lord Armstrong", p. 327).

After digressing into a description of technical education in America, Playfair further addressed himself to the question of technical education in Britain. In asking why ambitious men so willingly sacrificed their leisure time for attendance at evening classes, he suggested that it might be due to the division of labour whereby a man in one part of a factory knew nothing of the processes needed to complete the product on which he was working. Although this ignorance was of little consequence to the employer, it was essential to the self esteem of the workman that his intelligence should not be underrated nor his labour undervalued.

Playfair then discussed the continuing problem of the advance of new technology and its social and economic consequences. 'The rapid improvements in machinery', he observed, 'are producing constant dislocations in labour'. Although each new invention reduced the need for manual work, the resultant social consequences were of a temporary nature. In the long run, manual labour was replaced by intelligence. In this situation, he averred, those with only manual skills had most to lose. When trade depressions occurred, labour found itself divided into two categories - the labour of quantity, which would not survive the crisis, and the labour of quality which would. The former category equated with Armstrong's 'hewers of wood and drawers of water', for whom technical education had, apparently, little to offer. In the event, Playfair dismissed this thesis in arguments which would be appropriate today. 'Brute labour is continually decreasing in value as a factor in production. Labourers of this kind, pushed aside by machinery, are too familiar to us under the name of the "unemployed" - a class that is likely to increase in a dangerous way unless we cultivate their intelligence by a better education so as to enable them to pass from the ranks of the labourers of quantity into those of the labourers of quality'. (Playfair, "Lord Armstrong", p. 329).

Using the example of Bessemer's steel process, he recalled that its introduction had made 39,000 men redundant. Those who were intelligent enough to adapt to the new practices continued in employment, but a great many of them 'never dreamt that their furnaces would go out'. A deeper understanding of this transition in their industry would have averted much of the misery endured by the workers.

Playfair agreed with Armstrong's assertion that artificers and those with higher industrial and managerial skills would benefit from technical education. Although he did not wish to quarrel with Armstrong over nomenclature, he was prepared to substitute the term 'trained intelligence' for 'technical education' or whatever name Armstrong desired, 'provided we can secure his valuable co-operation in promoting our object'. Indeed, despite their differences, it is evident that Playfair held Armstrong in high esteem and was prepared to go some considerable way in enlisting his support. 'We would welcome him as an ally', he averred, 'cool of judgement, unaffected by enthusiasm or emotion'. (Playfair, "Lord Armstrong", p. 330).

Reiterating the case for technical education, Playfair argued that 'an immense mass of ignorance has to be removed among the working men of this country'. Fortunately, he added, many recognised this and hoped that their children would enjoy the opportunities which they had been denied. To meet this need, the Association for Technical Education had been established. Indeed, Playfair claimed that the association contained 'young and enthusiastic workers, who will continue this work when advanced veterans like Lord Armstrong and myself are numbered among the great majority'. (Playfair, "Lord Armstrong", p. 331).

Throughout his speech, Playfair praised Armstrong's capabilities, but expressed regret at his seemingly unwarranted attack on technical education. Indeed, his words are so appropriate as to deserve being quoted in full:

> 'Lord Armstrong belongs to that distinguished body of engineers who have advanced so much the industries of this country. They are generally indifferent to technical education because they feel, with just pride, that their offices and workshops have been schools for engineers and have produced admirable men. It is true that the office of engineer aims only to teach the apprentice manipulative skills and construction work , leaving him to pick up scientific knowledge where and how he can. When engineers see that schools and colleges are actually furnished with workshops in which mechanical drawing is thoroughly taught and where pattern-making, moulding and founding form part of the curriculum , and an intricate acquaintance with the use of machine tools is given simultaneously with scientific education, the old engineers shrug their shoulders and approve of Lord Armstrong's attacks on the new modes of technical education'. (Playfair, "Lord Armstrong", p. 331).

Playfair averred that the system of apprenticeship, by which British engineers were trained, was acknowledged to be highly efficient, yet there were some industries which failed to give methodical training. It was to apprentices in these factories that technical education was essential. Indeed, he argued, there was an increasing demand for more systematic training than that of the workshops, even among the engineers themselves. This was apparent, he claimed, in the argument that better engineers were produced after three years in college combined with two years in the workshops than after five years in the latter. 'The proof of this', he declared, 'is that there is an active demand for men trained in this way'. (Playfair, "Lord Armstrong", p. 331).

He supported this argument by recalling that the original system of apprenticeship adopted by all trades was adequate 'when industries were carried on by rule of thumb and not on scientific principles'. Even doctors were taught in similar fashion until their education had to be formalised 'for the safety of the public'. (Playfair, "Lord Armstrong", p. 332). Moreover, he argued that in modern competitive industry, the master craftsman had been replaced by the capitalist who, with his wider commitments, no longer felt any personal responsibility towards his apprentices. Thus it was the duty of technical schools to teach the scientific principles underlying their industries. Unfortunately the employer did not always welcome such intervention chiefly because it was more profitable for a worker to remain constantly at one specific task, rather than to be aware of the whole operation. Only the economic benefits arising from the promotion of technical education would persuade the manufacturer to change his methods.

Accusing Armstrong of failing to make any new proposals, Playfair argued that when he realised that the other industrial nations of the world were promoting technical education and trying to surpass each other, he might regret his untimely intervention. Indeed, Playfair acknowledged that Armstrong was 'the last man who would desire that the working men in England should continue to remain, in reality, what they were in name - the mere "hands" of the workshop - without having their "heads" full of trained intelligence to guide their work'. He further argued that, in a world where trained intelligence, rather than the location of natural resources, was the vital factor in production, it was necessary for workmen to have an intelligent knowledge of the whole manufacturing process in which they were engaged.

'The great industrial machine of this country', he concluded, 'is good enough in itself, but it needs proper oiling to make it work smoothly; the lubricant which it so much requires is the technical education of the productive classes'. (Playfair, "Lord Armstrong", p. 333).

Naturally, Armstrong did not allow Playfair's rejoinder to go unchallenged, and his reply was both immediate and forthright.

"I am glad", he began, "to find that my paper has met with much more concurrence than dissent and I am also grateful to observe that such of my critics as have disagreed with me have expressed regret at my inability to join their cause rather than reproach for my having discouraged it". (Lord Armstrong, "The Cry for Useless Knowledge", The Nineteenth Century, Vol. XXIV, No. 141, November 1888, p. 653).

Although Armstrong acknowledged the amount of common ground between them, including the fact that reform in education was necessary, it was the manner of such reform that caused dissent. (Armstrong, "Useless Knowledge", p. 653). He confessed to being a supporter of technical education, but was not so enthusiastic as some of his critics.

With reference to an anonymous article in Nature, he noted that he was purported to be 'a true representative of that remarkable genius the practical Englishman who has been the glory of his race in the past, but threatens to be its destruction in the near future'. (Anon, "Lord Armstrong on Technical Education", Nature, 2nd August, 1888, p. 313).

Although the article acknowledged Armstrong's reputation as a mechanical engineer, it concluded that 'few will regard him as an "unimpeachable authority" in the matter of technical education. If the majority remain much longer of his opinion, then is the fate of our nation sealed'. (Anon, "Lord Armstrong", p. 314).

To this "wail at the end", Armstrong retorted:

"Well, I have passed through the phase of being treated as an amateur and a theorist not likely to succeed for want of practical acquirements, and now I have arrived at the contrary phase of being treated as an old fashioned man of practice, deadened to the claims of theory and new ideas. I must leave my friends to judge which extreme I belong to, or what my place is between the two". (Armstrong, "Useless

Knowledge", p. 653).

Perhaps because of Playfair's academic standing, or because the other replies were anonymous, his article received special attention.

Armstrong's legal training is evident in the manner of his criticism, if not in the substance, when he noted that Playfair, "instead of replying to my arguments point by point, directs his chief efforts to minimising the differences of view that exist between us". To Playfair's suggestion that he should join the Technical Association, Armstrong replied: "I return the compliment by observing that I should be equally glad of his alliance on the grounds of his philanthropy and influential name, though not on the score of the emotion with which he treats the subject".

Criticising Playfair for including specific trades in the scope of technical education, Armstrong argued, "in a manner which shall exclude ambiguity and misconception", that "workshops and factories or other places where business is actually carried on, are the proper schools for the learning of such trades. Here, at once, we stand face to face in diametrical opposition". (Armstrong, "Useless Knowledge", p. 654).

The fact that the Apprentices' Training School at Elswick was still existing, even in the days of comprehensive education, seems to give weight to this argument. Nonetheless, were they so opposed, considering that Armstrong's own workmen had the best of both worlds, through his provision of the Elswick Mechanics' Institute and his support of the College of Physical Science in Newcastle? Although Armstrong argued the case for 'on the job' training as opposed to 'technical education', the geographical lay-out at Elswick was such that theory and practice in the Mechanic's Institute and the factory existed, literally, side by side. Would it not, therefore, have been expedient for Armstrong to agree with Playfair; to strive with him for the furtherance of the Elswick example in every industrial location and to make appropriate provision for the remainder?

The trained lawyer would not accept appeasement. The case had to be won or lost on the evidence presented. Thus, he ignored the opportunity and demolished Playfair's other arguments, especially his assertion that technical education aimed at giving 'an intelligent knowledge of the sciences and arts which lie at the basis of all industries'. Taking Playfair's premise that if technical education was given at public expense to tailors, bricklayers and watchmakers, where could we draw the line? In London alone, he argued, there were over 4,000 industries, all of which involved as much art and science as craft skills. "Now if Professor Playfair contends for this wholesale instruction at public expense, his contention is simply impracticable", he claimed. "If on the other hand, he makes a selection, it is manifestly unfair".

Continuing thus, he made his coup de grâce by affirming his view that the number of people whose business acumen would be improved by technical education was very small indeed. He corroborated his argument by references to his own experience. He recalled that the Elswick Company "many years ago provided extensive schools in connection with their works and a Mechanics' Institute which now possesses a copious library and in which rooms are provided for evening science and art classes, conducted by able teaching". The Company's interest, he added, was evident in its constant monitoring of these facilities and its willingness to extend and improve the buildings "to keep pace with the increase of the neighbouring population". (Armstrong, "Useless Knowledge", p. 655).

The subjects taught in the evening classes tended to reflect the Company's involvement with mechanical engineering, naval architecture and building construction. Nonetheless, they also included chemistry, "for the teaching of which an excellent laboratory is attached". Not only was this acknowledged by independent observers to be the largest of its kind in the North of England, but its presence and high reputation testified to Armstrong's genuine belief in the advocacy of more scientific laboratories for general use. The curriculum included mathematics, electricity, sound, light and heat as well as drawing "in all its branches", plus French and shorthand. These subjects reflected both the scale and the total ambience of the business enterprise at Elswick, rather than 'technical education' in its narrow sense. The inclusion of French and shorthand shows that Armstrong's vision of such education was not constrained by monetary considerations since these subjects did not qualify for grants from the Science and Art Department. Indeed, the entire funding of his schools and science classes, including teaching and all current expenses was two fold. Grants from the Science and Art Department were supplemented "by a tax varying from 1d to 2d per week on the workmen employed by the Company according to the rate of wages they receive". The educational facilities were entirely "open to the use of the Elswick workmen and their families without further payment except that those who attend evening classes pay certain additional fees, varying with the number of subjects undertaken by each student, and which, if spread over the whole year would give, on an average, about 2d per week". (Armstrong, "Useless Knowledge", p. 656).

At that time, according to Armstrong, the Company employed about 13,000 men and boys, of whom 10,000 contributed weekly pence. Nor was the educational establishment a 'closed shop'. Strangers were admitted on payment of about double fees. This was an important concession in an area which had "a large adjacent population engaged in engine works, shipyards, foundries, forges, chemical works etc. all involving practical science to a greater or less degree and some sort of them in as high a degree as almost any other trade that can be named". Nonetheless, from such a catchment area the number of men and boys "who avail themselves of the cheap and effective instruction afforded by these evening classes is, on average, not more than 350 at one time".

Armstrong then made reference to "another important and ably conducted establishment in Newcastle", which gave scientific instruction. This was the School of Science and Art in Bath Lane, now part of the Newcastle Polytechnic. The original buildings have recently been demolished, but for many years it enjoyed a high reputation as Rutherford College, named after its founder, Dr J.H. Rutherford. The nearby College of Physical Science which later bore Armstrong's own name was, according to him, "doing very good work". Although he was "not in a position to speak with accuracy of the numerical results of these two institutions in relation to the surrounding population", Armstrong was "certain that the combined number of their voluntary students forms an extremely diminutive proportion of the people who might avail themselves of the proferred instruction if they were disposed to do so". Even allowing for the fact that some of Armstrong's chosen sample could have attended other Mechanics' Institutes in the area, this still would not have absorbed all the potential candidates then employed in heavy industry on the western outskirts of Newcastle. Thus, Armstrong's claim that lack of initiative, not lack of provision, was the root cause of failure, challenged Playfair's thesis that there was a genuine need for further educational facilities. Armstrong further argued that "if the proportion of persons aspiring to scientific knowledge be so small in the case of industries like those practised on the banks of the

Tyne, what would it be in the case of industries which have no tangible connection with science?" He queried Playfair's example of the need for 'large Polytechnics' in the cotton spinning areas to which operatives would come 'in their thousands and tens of thousands', and asked "what are the sciences and arts which lie at the basis of cotton spinning, which is only one of many industries in which the same question may be asked without hope of a rational answer". (Armstrong, "Useless Knowledge", pp. 656 - 7).

Nonetheless, returning to the classes at Elswick, he discussed the advantages to both the students and the Company of the numbers then attending. Of these, about two thirds were journeymen and apprentices from the Works. The others, from other firms, often left mechanical work to find employment more in keeping with their newly acquired literary and scientific skills. Although he admitted that scientific instruction did not necessarily make a more skilful mechanic, it was a contributory factor in the promotion to foreman and beyond. Indeed, he argued that ability and good conduct weighed more than superior education.

Was Armstrong, at this point, playing Devil's Advocate? He was, after all, a lawyer by profession and thus well versed in the art of debate. Considering the time, money and energy that he, personally, expended in promoting the Elswick Works' Schools and Mechanic's Institute, his next argument is even more remarkable than the last.

"As to the advantages resulting to the Company from this scientific teaching, it improves the class of persons from whom selections are often made to fill vacancies in positions above those of ordinary workmen; but it would be absurd to say that the successful competition of the Company with foreign manufacturers is in any degree due to the educational measures it has taken. This is a plain unvarnished statement of the economic advantages to the students attending these classes and the Company who supports them". (Armstrong, "Useless Knowledge", p. 657).

However, he did concede that: "When the advantage to the students is viewed in the light of mental culture and refinement, it must be estimated at a much higher standard. Whether knowledge in science and literature be acquired by reading and study or obtained through the instrumentality of teachers, its effect on elevating the intelligence, expanding the intellect and opening out pure sources of enjoyment in displacement of evil ones is beneficial in a very high degree and I think it no small thing that 350 students should, in every two or three years, leave the Elswick classes to impart a wholesome leaven to the great working population of the district". (Armstrong, "Useless Knowledge", p. 657).

After dismissing Playfair's arguments on the need for technical education to counteract the 'decadence of apprenticeship', Armstrong returned to his former argument that men "who had made great names in the world had educated themselves in such knowledge as was necessary to the exercise of their talents". He refuted Playfair's premise that while men of genius could overcome the defects of their education, it was necessary to make appropriate provision for the rest. He argued that: "The self made man, or in other words the self educated man, may almost be regarded as the prevailing type of successful man and it is clearly an open question whether their number would be materially increased by additional facilities for obtaining scientific and technical knowledge. If Professor Playfair looks around him, he will see that 'the men who carry on the great industries of nations' so far from being rarely in this category of self made men, predominate in it". (Armstrong, "Useless Knowledge", pp. 658 - 9).

To Playfair's other argument that 'the great revolutions of history are generally produced by outside men of genius who are not driving in the usual ruts of an industry but who view its needs from without', Armstrong gave this rejoinder: "I should have thought that the man of genius working inside of an industry had a much better chance of comprehending its needs that one who viewed it from without. As to the danger of getting into ruts, it appears to me that there is much more danger of getting into academic ruts. If George Stephenson, for example, had fallen into the hands of professors at an early age he might have got into a rut leading to pedantry instead of practice; but I know of no misleading ruts in the school of observation and experience". To those who suggested that George Stephenson might have been more successful with the advantage of education, Armstrong argued: "That he did achieve great success without education is a fact; that he would have done more if educated is only a hypothesis, which is counter-balanced by the opposite hypothesis that he might have done less". (Armstrong, "Useless Knowledge", p. 659).

Playfair's theory that 'technical education may contract the originality and power of work', prompted Armstrong's reply that "I not only think that it may, but that it does when it assumes the form of cramming, for it is easy to put out a fire by too much fuel".

He next considered Playfair's argument that 'George Stephenson felt his own want of education so keenly that he took care that Robert, his son, should have the best education within his reach'. To this Armstrong argued that "Robert Stephenson was a man of good general education and was also well versed in scientific and technical knowledge; but that knowledge was not acquired in technical schools or colleges such as are now being called for, but from ordinary school education and the practice of his profession combined with reading, study and experiment, or, in other words, chiefly by self education for which he enjoyed facilities which fortune denied to his father". (Armstrong, "Useless Knowledge", p. 660).

Armstrong further argued that it was inevitable that George Stephenson should feel so keenly his general want of education. He was unable to read or write until he was grown up, and even then, somewhat imperfectly. No evening classes, no free libraries and no cheap educational literature existed for him. At first, he moved among those who were as little educated as himself, but when he rose to fame his lack of education became all too apparent. When he realised his disadvantage, he was determined that Robert should never labour under a similar difficulty.

Then Armstrong referred to an article by Professor Ramsay which took a more rational view of education applicable to industry than the rest. Ramsay noted that the demand for technical education came neither from men of science nor from the great employers of labour. 'On the contrary', he claimed, 'in our great commercial cities, nothing is more remarkable than the scepticism or indifference as to the value of technical education which is exhibited by our captains of industry'. (G.G. Ramsay, "Technical Education", Blackwood's Magazine, Vol. CXLIII, March 1888, p. 426).

Continuing on a similar line to Armstrong, he argued: 'If the opinion of any able practical man at the head of a large works be asked on the subject the invariable reply is, "Well, I should like to know what you mean by technical education", and he will probably add that the present cry for it is being much overdone and may lead the nation off in an entirely wrong direction'. (Ramsay, "Technical Education", p. 426).

Like Armstrong, he deplored the fact that the 'manufacture of coal-tar dyes is perhaps the most notorious instance of a trade being carried off from under our very noses by the superior scientific and industrial capacity of another nation. The products of the distillation of coal tar, the raw material from which Germany makes the beautiful dyes for which our manufacturers are the chief purchasers, are supplied mainly from this country, simply because we have not the brains or the skill in our own country'. (Ramsay, "Technical Education", p. 431).

He argued that the reason for Germany's supremacy in this regard, 'with every single economic point against them', was because their chemical industries were 'under the complete control of the highest scientific capacity which they can command'. (Ramsay, "Technical Education", p. 432). Nonetheless, he concluded his article by expressing the hope that any schemes for technical education in this country would be biased towards education rather than technology.

In reply, Armstrong acknowledged that Ramsay, "as a champion of scientific education" wanted to trace this particular deficiency to "the want of scientific colleges in this country for obtaining a high class chemical education". For his part, he attributed it "to the apathy and want of enterprise" on the part of our own manufacturers "who failed to procure the scientific assistance essential for their trade". (Armstrong, "Useless Knowledge", p. 661). Moreover, when Ramsay argued that Britain only trailed behind Germany in specific cases he had, according to Cardwell, 'a powerful ally in Lord Armstrong'. (Cardwell, p. 159).

To Ramsay's assertion that success requires the aid of talented specialists who were not available in England, Armstrong argued that they were here, but reiterated that the English manufacturers failed to use them. "The simple truth", he claimed "is that the English dye manufacturer has less pluck and enterprise and therefore he is beaten, and no amount of chemical colleges would save him from being beaten". (Armstrong, "Useless Knowledge", p. 661). By contrast, he suggested that we were pre-eminent in the smelting of iron, although the economical working of the blast furnace required a high degree of chemical knowledge. In this case he argued that, to remain competitive, the ironmaster was faced with a choice of either making himself an expert in the appropriate branches of chemistry or of employing specialists who were. "Those specialists", he maintained, "are to be got in England, (because) there is a demand for them and nobody pretends to say that the foreign specialist is in this case superior to the English one". (Armstrong, "Useless Knowledge", p. 662).

Nonetheless, he argued, because the number of industries requiring high chemical or scientific knowledge was very limited, the demand for chemical experts must be correspondingly small. Even so, his support of places like the College of Physical Science in Newcastle becomes evident in his next remark:

> "I am not adverse to high college education in chemistry or other physical sciences any more than I am adverse to the teaching of high mathematics in universities, for it is obvious that the literature of all these subjects would be much impoverished by the absence of such high education". (Armstrong, "Useless Knowledge", p. 662).

Even so, he considered that the economic value of such education was highly overrated and that sound, practical results were consistently attained by those who used the facilities generally available and "mastered scientific information to whatever extent it is necessary to the prosecution of their researches or the attainment of their ends". (Armstrong, "Useless Knowledge", p. 662).

Armstrong next returned to his original argument that "a man's success in life depends incomparably more upon his capacities for useful action than upon his acquirements in knowledge, and the education of the young should therefore be directed to the development of faculties and valuable qualities rather than the acquisition of knowledge". (Armstrong, "Useless Knowledge", p. 664).

None of his critics, he claimed, had even touched upon this salient point. Indeed, he suggested that "they fear to do so, being aware, as everybody is, that men of capacity and possessing qualities for useful action, are at a premium all over the world, while men of mere education are at a deplorable discount". He supported this theory by arguing from his experience at Elswick where educational attainments were cited by applicants seeking employment, yet they carried little weight in the final selection. "I can affirm with confidence", he maintained, "that had I acted upon the principle of choosing men for their knowledge rather than their ability I should have been surrounded by an incomparably less efficient staff than that which now governs the Elswick Works". Nevertheless, he conceded that far from despising knowledge, he valued it as highly as anyone, yet despite its worth as an intellectual occupation or as a mental stimulus he was afraid "that its economic value in the ordinary vocations of life which give employment to the multitude is exceedingly small". (Armstrong, "Useless Knowledge", p. 664).

Did Armstrong really believe that education could only be measured by a balance sheet? If so, despite Playfair's gracious overtures, there must have been little common ground between the educator and the engineer.

Whatever his motivation, Armstrong sought tangible proof that

Germany's high pressure education posed any real threat to our commerce, and until that was forthcoming, he argued, we should not make hasty decisions in following her example. According to him, the German people themselves were far from unanimous in their approval of the system and many dreaded its ultimate effects. He agreed with that body of opinion which considered that it was "thrown away upon the mass of the population and is debilitating both mind and body by the overstraining of the faculties".

This theme of overstrain led him to attack the examinations system which was gaining ground in this country. Indeed, he was to criticise it, with increasing vehemence, later. Mothers, he claimed, saw their children's health suffer, "while ratepayers groan under educational burdens for which no adequate benefits can yet be shown". (Armstrong, "Useless Knowledge", p. 665).

He then returned to attack Playfair for requesting scientific training for men like tailors and bricklayers, yet making no similar plea for "that great industry with which he himself is associated and which, almost more than any other, requires 'an intelligent knowledge of the science and art which lie at its basis' ". If teaching were to be organised along scientific lines, he argued that its present difficulties would vanish, "and education would become what its name implies, a drawing out or development of mental faculties with the least possible waste of energy and with concurrent advantages to physical powers". (Armstrong, "Useless Knowledge", p. 665).

He considered that the principle of education through exercise and enjoyment, found in infant schools, was worthy of deeper consideration. Although he acknowledged that such a programme would be difficult to adapt to the needs of older pupils, nonetheless, he felt that there must be an answer to the problem of training the mind while improving the physique. Yet no answer was forthcoming, nor would it be, until the matter was thoroughly investigated by scientific methods involving experiments and trials. But, he regretted, nothing like this was attempted by our educational experts. Instead the cry was for cramming and higher education which, he averred, meant more knowledge.

School education should aim at the development of character and the preparation for self education. Pressing his case further, he declared that men should not be carried when they can walk, but be trained to exercise independence of mind and freedom of action. This observation caused him to renew his argument that self education, not school education, was better for responsible adults.

"Self education", he claimed, "may consist either in the acquisition of ideas which flow from observation, experience and thought, or in the appropriation of ideas emanating from the minds of others". Unfortunately, the latter would be "little sought for by the multitude". (Armstrong, "Useless Knowledge", p. 666). Facilities for such education should be made available to those who required them, but, given that premise, how far were the existing ones already adequate? In this event, he did not envisage that very ambitious extensions would be necessary to meet the demand. He appreciated that the academic world tended to undervalue self education, despite the fact that it continued throughout life.

He took issue with his critics who suggested that he considered education merely in utilitarian terms. Although admitting the importance of moral and religious teaching, he did not consider them to be part of his remit. His subject, he averred, was "useful education" and he felt that he had fulfilled his brief if he had highlighted the popular tendency to overrate the value of knowledge and to underrate that of capacity.

"In the academic mind", he continued, "the intellect of the people is regarded as lying dead for want of knowledge. I speak as one of the educationally dead in saying that I have never had a scrap of instruction bearing on my profession beyond what I imbibed for myself and I feel it has done me incomparably more good than if it had been administered to me". (Armstrong, "Useless Knowledge", p. 667)

He categorically denied the suggestion that he was hostile towards education or to providing the means of attaining it for those in need of such services. His antagonism was reserved for those who, believing that 'knowledge is power', wanted to initiate expensive educational schemes. "Where natural capacity is wasted in attaining knowledge", he argued, "it would be truer to say that knowledge is weakness". (Armstrong, "Useless Knowledge", p. 668).

Thus, apparently, he was not against technical education as such, but the means of its implementation. Was Playfair right? Was there common ground?

Shortly after writing these articles, Armstrong was asked to sign a protest, which appeared in the same Review, deploring the pressures engendered by competitive examinations. Among the signatories were several other distingushed northerners, including Sir Edward Grey, later to become Foreign Secretary and Viscount Grey of Fallodon; Alfred and Arthur Pease, members of the Darlington Quaker family which helped to finance George Stephenson's Stockton to Darlington Railway venture; Thomas Hodgkin, who was one of the instigators of the College of Physical Science and Mark R. Wright, then Headmaster of the Gateshead Higher Grade School. (A. Herbert et al, "The Sacrifice of Education to Examination", The Nineteenth Century, Vol. XXIV, No. 141, November

1888, pages 623 - 636). In 1895, Wright became the first Professor of Education at the Durham College of Science, later Armstrong College, Newcastle, only five years after the Education Training Department was established. (E. Bettenson, The University of Newcastle upon Tyne, 1834 - 1971, 1971, p. 27).

The protest, which reaffirmed many of Armstrong's arguments, deplored the ideal which was gaining popularity whereby young children were being treated 'as suitable instruments for earning Government money'. (Herbert, 1888, p. 617). It further argued that capable young men in the Universities were taught to believe that the prime objective of education was to enable them to win great monetary prizes or honours in an examination, while young people from all social classes were being trained for competitive examinations in the same way as young race horses and with as little regard for their future.

From the outset, the signatories deplored the failure to acknowledge both the true purpose of education and the physical damage imposed by competitive examinations during a child's formative years. They forecast that if the system continued, the most serious intellectual and moral consequences would follow. Instead of 'every science such as education' depending on the emergence of new ideas, the examinations system encouraged education of only one kind, with teaching geared solely to the winning of coveted prizes. Such uniformity prohibited growth and accelerated decay, while the very diversity of true education meant renewed vigour and limitless adaptation.

The best teaching, they affirmed, was subjugated by the over-riding demands of examinations. The teacher's own interest in specific aspects of his subject was sacrificed to the same demands and by his natural desire for his pupils' success. In turn, the pupils were willingly guided by the lure of distant prizes. 'What will pay', was a greater principle in education than the pursuit of knowledge for its own sake. 'The constant opening up of new interests', they argued, 'are the great stimulents to self-development, and they should be ever spurring the student on to endeavour to know more and to see more clearly. We hold that these life-giving interests cannot possibly co-exist with the repressing influences of training for great examinations'. (Herbert, 1888, p. 619).

Furthermore, they argued that the present system not only obscured the true value of different kinds of education, but the more important controversies like those between the classics and the sciences or between the various methods of teaching. The pressure to succeed in examinations encouraged the deplorable practice of rote learning while discouraging the more desirable accomplishment of rational debate. Indeed, they roundly condemned the practice of mental energies being dissipated solely for the purpose of monetary gains rather than for the development of the faculties of reason.

The waste of teachers' time on the drudgery of examinations had a debilitating effect, and education had become 'a body without a soul'. The true aim of education, they declared, was preparation for life, and no nobler influence could be brought to bear upon the young than the desire for knowledge to achieve that end. (Herbert, 1888, p. 620).

An examination was a good servant but a bad master. It was a useful tool in the hands of the able teacher who wished to test his own work or that of his pupils. Yet when examinations became the ultimate aim, teachers simply conformed to external pressures; lost faith in themselves; became slaves to their own text books, and gave little of their own personality to their work.

'If examinations are to be defended on the ground that they test the efficiency of teachers', they concluded, 'then we reply that other and better ways of doing this are to be found'. (Herbert, 1888, p. 621).

The response to the protest was so overwhelmimg that 'the whole Review might be filled with extracts' from the hundreds of letters received, and 'from articles dealing with the subject'. (A. Herbert et al, "The Sacrifice of Education to Examination", The Nineteenth Century, Vol. XXV, No. 144, February 1889, p. 284). Teachers of all grades from the Universities downwards were 'unanimous as to the need for some change in the present system, while parents and doctors confirm the widespread discontent and give abundant evidence in justification of it'. (Herbert, 1889, p. 284). In addition, a hundred Members of both Houses of Parliament, including Lord Armstrong, were among the signatories. Several other eminent men, including Dr Priestley and the Bishop of Carlisle, added short articles to the protest, expressing their support. (Herbert, 1889, pp 286 - 322 passim).

The examinations system, which was introduced to eliminate patronage and to promote equality of opportunity, was associated with the establishment of the Science and Art Department, and encouraged by men like the Prince Consort and Playfair. (Cardwell, p. 37). Equally, the examinations of the Society of Arts were intended to promote the work of the Mechanics' Institutes and to bring ambitious artisans within the system. The momentum thus engendered was boosted still further with the establishment, in 1880, of the City and Guilds of London Institute and by its promotion of the first English Technical College at Finsbury a year later. (Argles, p. 23).

Armstrong had other supporters. In 1868, Matthew Arnold had published a book on the schools and universities of Germany and how far England could learn from them. (Cardwell, p. 141). He argued that neither Oxford nor Cambridge encouraged science and London University was little more than an examining board. By contrast, the German Universities, whose doctorate degrees required evidence of original work through a thesis, showed greater academic rigour than their English counterparts where the 'degree examination itself is the grand final cause of university life'. (Quoted in Cardwell, pp 142-3).

A detailed analysis of Arnold's arguments is inappropriate in the present context, but it should be noted that Armstrong's views, rather than Playfair's, were nearer to those of Her Majesty's Inspector.

Meanwhile both the curriculum and its attendant examinations were becoming more specialised. Despite the general desire for liberal and comprehensive education, endorsed by the Devonshire Commission, specialisation was increasingly introduced. For instance, the original London University B.Sc. degree was designed to ensure 'such general culture as should be likely to prevent its holder from being a mere specialist'. By May 1876 the same University agreed that 'a thorough knowledge limited to a comparatively small range is preferable to a slighter acquaintance spread over a more extended area' because 'teachers and examiners assure us that this is best'. (Quoted in Cardwell, p. 147).

With the weight of such authority, it is not surprising that these views became entrenched. Nonetheless, specialisation had its critics, including Playfair who, in 1885, condemned it in his Presidential address to the British Association. 'The divorce of culture and science, which the present state of education in this country tends to produce', he argued, 'is deeply to be deplored because a cultured intelligence adds greatly to the development of the scientific faculty'. (Quoted in Cardwell, pp. 149 - 150). In views similar to Armstrong, he had criticised written examinations on the grounds that they 'created faithful disciples rather than independent thinkers'. (Quoted in Cardwell, p. 150).

The debate, involving many of the highest academics of their time, rumbled on into the next century. Indeed, it emerged in the Spens Report in 1938, in the context of the School Certificate Examination. Although the Report acknowledged that the examination 'has performed important services for the education provided by Grammar Schools' there were reservations from teachers and others which are noteworthy in the context of Armstrong's views. The two main criticisms were the effect on the children's health and on the curriculum.

First, the Report acknowledged that: 'we hold that in several important respects the influence of the examination and the process of preparation for it are inimical at present to the healthy growth in mind and body of a large number of children who pass through the Grammar School'. (Board of Education, Report of the Consultative Committee on Secondary Education, 1938, p. 256). Furthermore, it was noted as 'a point of much significance' that at the inception of the School Certificate Examination in 1918, the Board of Education issued a circular specifically stating that it was "a cardinal principle that the examination should follow the curriculum and not determine it". (Board of Education Circular, 1034, March 1918. Quoted in Spens Report, p. 257). The Report added that: 'We cannot fail to note that in practice this has been reversed'. It concluded that the requirements of the examinations forced the schools to teach certain subjects to the detriment of others even when the pupils 'might be deriving greater benefit from taking alternative subjects or from taking fewer subjects to a higher level'. (Spens Report p. 257).

Remarkably, these were among the main planks of Armstrong's arguments, fifty years earlier. Thus, although he made no claim to being an educator, his views were in line with the wider movements of thought and action even in the twentieth century. Moreover, they were shared with men of such professional standing as Ramsay and Arnold, while even Playfair himself sought him as an ally.

CHAPTER XVI.

"THE IMMENSITY WHICH LIES BEYOND".

"The tendency of progress is to quicken progress, because every acquisition in science is so much vantage ground for fresh attainment. We may expect, therefore, to increase our speed as we struggle forward; but however high we climb in the pursuit of knowledge, we shall still see heights above us, and the more we extend our view, the more conscious we shall be of the immensity which lies beyond".

When Armstrong spoke those words in his Presidential Address to the British Association in Newcastle, in 1863, how far was he composing his own epitaph and how far was it a just appraisal of his contribution to Science and Education?

From the mid 1860s, Armstrong was less personally involved with the daily management of Elswick and more involved in national affairs and his own research. Nonetheless, he remained head of the Elswick firm until his death.

Cragside, his home near Rothbury in Northumberland, increasingly became the centre of his activities, especially his scientific research. Here, he not only enlarged the house and grounds, until the estate reached 1,729 acres, but his passion for hydraulics and for the burgeoning science of electricity was given full rein. Here he erected no less than five artificial lakes including a dam which powered a hydraulic ram supplying water to the house and grounds. The lakes, too, supplied water for the hydraulic passenger and service lifts in the house and for the roasting spit in the kitchen.

The electrical researches of Armstrong and his friend Joseph Swan came to fruition when, again using the abundant supply of water from the lakes, Cragside became the first house in the world to be lit by hydro-electricity. In 1878, arc lights were installed but, two years later, these were replaced by Swan's invention of incandescent lamps. During the day, according to Armstrong, "the turbine and generator are occasionally used for the transmission of motor power to a second dynamo-machine acting as a motor to drive a sawing machine". (Quoted in McKenzie p. 109). Thus, Cragside was a fit setting for entertaining on a grand scale and his guests included the Prince and Princess of Wales (later King Edward VII and Queen Alexandra) and their children.

As a national figure, Armstrong attracted the attention of politicians of both Conservative and Liberal parties. Reluctant to start yet another new career, so late in life, Armstrong refused, at first, to be drawn. Nonetheless, in 1886, in his seventy sixth year, he was persuaded to stand as the Unionist Liberal candidate for Newcastle. Although Gladstone won the General Election, Armstrong lost locally. This was his first and last Parliamentary contest. Two months later he was presented with the Freedom of Newcastle and in June 1887, in commemoration of Queen Victoria's Jubilee, he was elevated to the peerage with the right to sit in Parliament without the hassle of the hustings. As Lord Armstrong, he was given the honour of seconding the Address in reply to the Speech from the Throne. (E.R. Jones, "Lord Armstrong", The Monthly Chronicle of North Country Lore and Legend, Vol. III, No. 23, January 1899, p. 5). His attitude to politics is summarised in a letter to George Rendel of 24th November 1889. "It is dangerous to meddle with public affairs if one wishes for peace and quiet as I do".

Meanwhile, what of Armstrong's contribution to the College of Physical Science? Although he served as a member of the College Council from its inception to his death, Armstrong does not appear to have been involved in its day to day running. Nonetheless, his name was inextricably linked to the most important milestones in its history until it finally became Newcastle's memorial to one of her most illustrious sons.

The first accommodation of the fledgeling College was 'in the attics and cellars' of the Mining Institute. The successor to Professor Freire Marecco, who became Professor of Chemistry in Armstrong College, described those early days. 'The Session 1871 (began) in premises consisting of half a dozen rooms on the top floor of the Coal Trade offices, Neville Chambers, a lecture theatre (!) in the basement of the Wood Memorial Hall, and rooms at the back of the College of Medicine at Westmorland House adjoining the Coal Trade buildings. The privilege of using the Library of the Mining Institute and the use, for ceremonial occasions, of the Wood Memorial Hall and the easy access to the Library of the Literary and Philosophical Society afforded some compensation'. (P. Phillips Bedson, "The Jubilee of Armstrong College", Durham University Journal, December 1921, pp. 348-349). The administration of the College and the Meetings of the Council were held in rooms rented from the Coal Trade, while its Secretary was also the Registrar of the College. (Bettenson, p. 22). Nonetheless, the dignity of the Wood Memorial Hall and the accessibility of the two excellent libraries 'appeared to hypnotise the Governors and other friends of the College into forgetfulness of the insufficiency of the accommodation and the unsatisfactory conditions under which the work had to be carried on'. (Phillips Bedson p. 349).

With the incorporation of the College under the Board of Trade in 1883, the name was changed to the Durham College of Science. A period of comparative calm during the first thirteen years was followed by frenetic activity during the next decade. A new site was imperative and the Council were anxious to find one suitable to the growing needs and enhanced status of the College. In the event, the urgent expansion of industry, rather than of education, gave the spur. The North Eastern Railway Company, in whose development the two Stephensons had played such a notable part, planned to extend the Central Station. Thereupon, they gave a deadline date for the purchase of the site at Westmorland House on which the College of Medicine stood. (Minutes of the Council of the Durham College of Science, 1st December 1884).

At first, a new site appropriate to the needs of both Colleges was considered and several locations came under serious review. Finally, with Armstrong's written approval, the College of Science purchased a site near Barras Bridge known as Lax's gardens. (Minutes Durham College of Science, 3rd May 1886). The College of Medicine vacated Westmorland House and moved into premises in Northumberland Road. Of the two sites, Lax's Gardens proved to be the more inspired choice. Over the years, the judiscious purchase of adjoining property and land has ensured the development, in one complex, of the modern University of Newcastle upon Tyne. Since 1937, when Armstrong College merged with the College of Medicine to become the Newcastle Division of Durham University, this complex has included the Medical School with its own adjacent teaching hospital, the Royal Victoria Infirmary, to whose inaugural funds Armstrong donated so handsomely. Thus, from a 'fitting institution in the heart of a coalfield' envisaged by the South Shields Committee, through the foresight of its early Council, including Armstrong, the edifice has grown into a 'fitting institution' in the heart of a city.

Building at Lax's Gardens began early in 1887 and on 15th June that year Armstrong laid the Foundation Stone of the new College of Science. Successive waves of expansion followed, even in Armstrong's lifetime.

After his death, this new building became the North-East wing of Armstrong College, which is now the Armstrong Building of Newcastle University.

As usual in the history of the College, the local press gave full coverage to the laying of the Foundation Stone of the new College of Science. Indeed, the Editorial of the Newcastle Daily Chronicle gave such a detailed account as to be worthy of more than passing reference, especially in the context of Armstrong.

It recorded that the engineering department of the College would be 'specially adapted for training apprentices and draughtsmen from the engineering and shipbuilding works of the Tyne, Wear and Tees'. Evidence of the close association between the College and industry is seen in the fact that a 'complete scheme for the engineering section has been drawn up by the committee of the North East Coast Engineers and Shipbuilders' and was distributed at the official luncheon which followed the foundation ceremony. (Newcastle Daily Chronicle 16th June, 1887).

The Mining Institute whose members, through many vicissitudes, kept alive the campaign for such a College, appointed a committee to draw up a parallel scheme for training mining engineers. Moreover, it was anticipated that a similar arrangement had been made on behalf of the chemical industries of the Tyne by their professional association.

The engineering laboratories were to be located on the South-West side of the College and the complete scheme was to cost about £25,000 although only about £15,000 would be required at the outset. When fully operational, it was envisaged that a large number of day students would be attracted who, by paying remunerative fees, would contribute largely to the incidental expenses of the department. Nonetheless, it was clearly envisaged, from the outset, that one of the main objects of the scheme was to provide for the apprentices and draughtsmen already employed in the region. Thus the attendance of day students 'must be regarded as an incidental rather than an essential part of the scheme'. (Newcastle Daily Chronicle 16th June, 1887).

At that rate, despite the College's named association with Durham, Nicholas Wood, Isaac Lowthian Bell, Armstrong, and the other enlightened industrialists, had won their protracted battle with the theologians and academics. At last they had erected an institution where young aspiring engineers, especially those from local industry, could be professionally trained in a constituent college of the University. In the context of 'the immensity which lies beyond' this aspect of the work of the College could be seen as an advanced version of Armstrong's educational scheme at Elswick, with its Mechanics' Institute and Day Science Classes.

In inviting Armstrong to perform the stone-laying ceremony, Dean Lake indicated that 'this is not the first of many of the good and great works - for we trust that this will be a great work - that Sir William has inaugurated, and not only inaugurated but completed in Newcastle'. Then, in a statement which was to prove prophetic, Lake hoped that, 'for many a long generation his name will be associated with its success'.

Armstrong reserved his speech until after the luncheon which followed the ceremony. In introducing him, on that occasion, Lake expressed his own faith in the future success of the College because he was sure that: 'not only Sir William but many other citizens of most powerful mind, of knowledge and goodwill towards the highest interests of the neighbourhood would agree with him in saying that it is an object of the very first importance that they should have an admirable college devoted to the interests first of Science and, ulimately, as he trusted, of literature, established amongst them'.

In proposing the principal toast to 'The Durham College of Science', Armstrong hoped that this would be the starting point in the history of the College. Hitherto, he claimed, its career had been disappointing, but with the facilities afforded by the new buildings, they could "look for better results in the future, especially from the practical tendencies of those who would have the direction of the instruction of the new college". The syllabus seemed to indicate that "the college instruction of the future (would) be more practical, more technical and less academic than hitherto". This he, for one, endorsed.

With his customary vision of the future, he suggested that what was required in the United Kingdom was instruction which would enable the rising generation to apply science to the business they pursued. "In other words, to use a homely expression, we need a 'bread-winning science' ". Moreover, he was afraid that, because this country was behind hand in that description of science, foreigners were steadily gaining ground. This, he maintained, was serious because no other country in the world was so dependent on manufacturing industries as our own.

The Americans, he averred, "mixed more brains with their fingers than we did". This was "because there were better opportunities and more inclination to cultivate the practical sciences". By contrast, he maintained, the British workman was "too prone to pride himself upon the efficiency of his manual labour and to regard the intellectual element of labour as a matter of inferior importance".

He then recalled the motto over an old house in Newcastle:

"By hammer and hand all artes do stand".

The meaning of that, he claimed was that the hand and tools were entitled to the foremost place in all the constructive arts. Nonetheless he argued that:

"Those who hold the opinion that labour, in the manual sense, is the source of all wealth forget that the hand, admirably adapted as it is to all human work, is never more than the tool of the mind. Even in the humblest forms of labour, the mind is the true operator and the hand the servant. The mind designed, organised, directed, arranged and so forth and it is in this capacity that the mind is the real source of wealth. Where would industries be without it? What would they be if we failed, in this country, to keep pace with our foreign competitors in the cultivation of the mental element of labour". (Newcastle Daily Chronicle 16th June, 1887).

It was to supply this want that more colleges were needed and he most sincerely hoped that "the Durham College of this town would be the means of supplying this need in the district". To this end, he proposed: "Success to the Durham College of Science". (Newcastle Daily Chronicle 16th June, 1887).

Another article in the same paper gave a useful summary of the situation. It observed that whenever the subject of technical education was raised, 'a great injustice is usually done to England'. Thus, the writer considered that it was a source of great satisfaction 'to learn from one so accomplished as Sir Lowthian Bell that, despite the advances of other nations, "England can still hold her own"'. The writer further considered that Armstrong's idea of a 'bread-winning science' was 'too gloomy'. Great engineers, he argued, 'are apt to take a pessimistic view of the situation'. Although he appreciated the reason for Armstrong's stance, he suggested that this was adopted because 'genius is apt to grow impatient of the slowness of progress and to expect better results than average humanity'. (Newcastle Daily Chronicle 16th June, 1887).

The official opening of the College, which took place on 5th November 1888, was performed by Queen Victoria's daughter, Princess Louise, Marchioness of Lorne, 'who has taken a prominent interest in educational work'. (Newcastle Daily Chronicle 6th November, 1888). The academic procession included evening students from the College's Department of Science and Literature and the Technical Department when the opening ceremony was held 'in the beautiful hall known as the Johnston Laboratory'. Thus the name of the scientist, whose pioneering work for the British Association and for Durham University has already been noted, was immortalised in the College soon to bear Armstrong's own name.

In contrast to all the previous speeches in connection with the College, the ones on this occasion seem to be more notable for their brevity than for their content. The seventy eight year old Lord Armstrong, on behalf of the President and Council of the Durham College of Science, thanked the Princess for performing the opening ceremony and the Marquis of Lorne briefly replied, on her behalf. (Newcastle Daily Chronicle 6th November, 1888).

For some time before the new building was opened, 'the premises of the College were unsatisfactory, its finances were uncertain and its intake of students erratic'. (Bettenson, p. 24). The turning point came when Professor Aldis, one of the original staff of the College, was appointed elsewhere and the Council had to find both a Professor of Mathematics and a Principal, with funds only for one. Despite the fact that the College could always rely on Armstrong's generosity in times of financial strain, the Council must have been relieved to receive an application from Dr Garnett, Professor of Physics, Mathematics and Mechanics at University College, Nottingham. Unfortunately, a man of his academic prowess was in great demand and, before he had been in Newcastle for two years, the City and Guilds of London Institute offered him the Principalship of their new College. Reluctant to leave

Newcastle, Garnett used his new offer as a subtle form of blackmail, by threatening to resign if the Council did not take immediate action on the question of College premises. In the event, the end justified the means and both the future of the College and Garnett's tenure in Newcastle were assured.

The Council opened a subsription list which was not very successful, and re-convened the Building Committee, including Armstrong, which, since before 1873, had been looking for a suitable site. When the one at Lax's gardens was under serious review, the College's finances stood at £40,000 with only Durham University subscribing more than £1,000 a year.

Realising the urgency of the situation, Garnett asked the organisers of the Exhibition, held in Newcastle in honour of Queen Victoria's Jubilee, to allocate the profits to the College. After the opening of the new building by Princess Louise, Armstrong offered to raise his last subscription from £1,000 to £2,000 provided adequate sums were forthcoming from other sources, and to donate an additional £50 a year for five years. (Minutes Durham College of Science, 10th November 1888).

In 1894, Garnett was succeeded as Principal by the Rev. H.P. Gurney. Among the priorities of the new incumbent was the completion of the College quadrangle. After the opening of the North-East wing by Princess Louise, the South-East and South-West wings were added in 1894, leaving the North-West wing to be built. When larger premises once more became a priority, Earl Grey presided at a meeting in Newcastle Guildhall, in September 1900, and inaugurated the College Completion Fund. Donations were slow in materialising but subtle blackmail again helped to achieve the impossible. This time the lure was the proposal that the completed College should be re-named Armstrong

College as Newcastle's memorial to the recently deceased Lord Armstrong. On 20th September 1901 a meeting was held in the Wood Memorial Hall, at which Earl Grey again presided. Here, the new (seventh) Duke of Northumberland proposed that: 'The life and work of Lord Armstrong ought to be suitably commemorated in his native city'. (Newcastle Daily Chronicle 11th July, 1906). The target for the project was £50,000 but the appeal reached only £40,000. When the remaining £10,000 was transferred from an earlier appeal by Gurney, 'the College saved face all round and, in 1904, the name Armstrong was somewhat unjustifiably attached to the College'. (Bettenson, p. 29).

'Somewhat unjustifiably' cannot pass without further comment. In view of the efforts of countless members of the Mining Institute, Nicholas Wood had, at least, as good a claim to commemoration as any other. For consistency over many years, Isaac Lowthian Bell stands high in the list of claimants. E.F. Boyd and Dean Lake deserve more than passing recognition for negotiating, so effectively, with some of the more obdurate members of the Senate of Durham University. Distinguished members of the staff of the College also deserve acknowledgement. Nonetheless, in view of Armstrong's outstanding contribution to engineering, science and education, in the wider context, as well as his many benefactions to Newcastle and the College, it is only fitting that his name should be perpetuated. Thus, an educational institution, originally devised for the study of his own specialisms, seems an appropriate memorial.

The Northerner, the College's own magazine, gives some useful glimpses into academic life at that time. One Editorial indicated that the change of name of an individual college was not all that was required. Already, at the turn of the century, the idea of a separate university in

Newcastle was being mooted:

'The past session has been an eventful one in the history of the College. It has witnessed the beginning of the new wing and the change of name of the College. No longer will we speak of the Durham University College of Science. We must adapt our unaccustomed mouths and ears to The Armstrong College of Science.

The building of the new wing ought to be but a further step towards the ideal. In a few years it ought to be possible to speak of the University of Newcastle. May that soon come!' (Editorial, The Northerner, Vol. IV May 1904 Number 5).

The same issue gave more details concerning the laying of the Foundation Stone and its enclosed parchment which indicated that this was 'the corner stone of the front wing of the Armstrong College of Science of the University of Durham, Newcastle upon Tyne, in memory of the Rt. Hon. William George, Baron Armstrong of Cragside, a native and notable benefactor of Newcastle upon Tyne, renowned for his inventive genius and scientific attainments'.

When the North-West wing, with its imposing frontage facing the Royal Victoria Infirmary, was at last completed, both buildings were officially opened by King Edward VII in 1906.

On this occasion, in reply to the Professors' Loyal Address of Welcome, the King spoke of the function of the College, both locally and nationally, and praised Armstrong's contribution to science and industry:

'Situated as your College is in one of the great centres of the industrial life of this country, I commend your wisdom in deciding that its teaching should be adapted as far as possible to the practical needs of your students. The name of Armstrong will always be identified with scientific discovery and industrial success and I am aware of the efforts which you have made, and have made successfully, to imbue your students with scientific principles. These principles are now more than ever necessary for the mental training of all who hope for success, either in the manufacture of raw products or in the great engineering works for which your city is famous all the world over. You may assure yourself that your contribution to the welfare of this great Empire is not small. Students are placed under your tuition at a most receptive age. Their future success in life is largely dependent on your guidance along the different paths of scientific investigation and the part which the tutors are called on to play is one of the very highest importance. The achievements of Armstrong College will always be watched by me with sincere interest and sympathy'. (Newcastle Daily Chronicle 12th July, 1906).

Apart from this mark of Royal approbation, the College was already being recognised as a centre of excellence in professional circles. For instance, in 1904, Newcastle Education Authority commissioned Professor (later Sir) Michael Sadler, then Professor of Education at Manchester and later Vice Chancellor at Leeds University. His remit was to report on the state of education in the city. The most relevant part of his report stated that: 'The crown of the educational system of Newcastle is the Armstrong College, the intellectual distinction of whose staff and the scientific value of whose work is recognised in educational circles all over the world'. (Quoted in Bettenson p. 37).

To the ordinary citizen, Armstrong was perhaps more renowned for his generous donations to worthy causes in Newcastle than for his scientifc genius. He had long been a true friend of the old Newcastle Infirmary where he provided the funds for a new wing and for an operating theatre. (Newcastle Daily Chronicle 27th December, 1900). Throughout the nineteenth century, the Infirmary was located at Forth Banks between the Central Station and the cattle market. Despite the generosity of Armstrong, Robert Stephenson and others, the site became more and more unsuitable as the volume of road and rail traffic increased. It was therefore decided to commemorate Queen Victoria's Diamond Jubilee by raising a sum of £100,000 for a new infirmary. Located on land at Castle Leazes, near the College of Science, and named the Royal Victoria Infirmary, it attracted benefactions from all sections of the population including both Armstrong and his heir, Mr William Watson Armstrong, who donated most generously.

Among an impressive list of benefactions, Armstrong's gifts of Jesmond Dene and Armstrong Park as well as several donations to the

Hancock Natural History Museum were worthy of Royal recognition and resulted in an official visit by the Prince and Princess of Wales to Tyneside, in 1884, when they stayed for several days as guests at Cragside.

On the first day of the visit, the Prince officially opened the grounds of Armstrong's Newcastle home, Jesmond Dene and the nearby Armstrong Park, which Sir William had donated in perpetuity to the citizens of Newcastle, subject only to an annual donation from the Council to the Infirmary. Together, these two parks 'constitute what is, admittedly, one of the finest parks in the Kingdom'. (Newcastle Daily Chronicle 27th December, 1900). In the afternoon, the Prince opened the Hancock Museum of Natural History and the Reference Library in New Bridge Street. The library was located in the building of the Newcastle Mechanics' Institute which had many links with the Literary and Philosophical Society and shared a common founder in the Rev. William Turner. The Mechanics' Institute had moved from its premises in Blackett Street, in 1866, but was later incorporated in the new Central Library in 1880. (Middlebrook, 1968, p. 309). In recent years this building has been demolished to create a modern library as part of the city centre's educational complex based on the University and the Polytechnic.

The Museum of Natural History, situated at Barras Bridge, near the College of Science, was named after the brothers John and Albany Hancock who were not only founder members, in 1829, of the Natural History Society of Northumberland, Durham and Newcastle upon Tyne, but strongly supported the campaign, in 1853, to have the College of Physical Science located in Newcastle. (Middlebrook, 1968, pp. 227 and 296). Armstrong himself joined the Natural History Society in 1846 and became a member of the Committee in 1847. He was Vice-President in

1861 and President from 1893 until his death in 1900.

The collections of the Natural History Society, after being housed in rooms behind the library of the Literary and Philosophical Society for over fifty years, were transferred to the Hancock Museum to which Armstrong and Lady Armstrong donated a valuable collection of shells as well as large monetary gifts.

The official historian of the Natural History Society, T. Russell Goddard observed that:

> 'The names of two North Country families will always be remembered with gratitude by all who care for beautiful things and take an interest in intellectual development, for it was the Armstrongs and the Joiceys who by their generous support enabled the Society to produce the finest building in Newcastle upon Tyne in which to expand its educational activities. Of the total of £38,000 subscribed, £30,000 was given by them. Sir William Armstrong, as he then was, and Lady Armstrong, subscribed between them £14,000'. (Quoted in McKenzie, p. 122).

The Natural History Society was one of many off-shoots of the Literary and Philosophical Society and was part of the educational enclave near the Central Station which included the College of Medicine, the College of Physical Science, and the Mining Institute. In line with the two colleges, the Natural History Society was forced to find new premises during the continued expansion of the North Eastern Railway Company. Nonetheless, while the Society was situated in close proximity to the Mining Institute, it amassed a unique collection of mineral and geological specimens and became 'the place of deposit for information connected with the collieries, by the formation of general plans which shall at once show the extent and position of the old workings of each seam'. (Quoted in Spence Watson, History of the Literary and Philsosophical Society, pp. 110 and 150). Thus it was a valuable adjunct not only to the Mining Institute but to the College of Physical Science.

In the context of Armstrong's gifts to Newcastle, Middlebrook observes that: 'Lord Armstrong was perhaps the greatest benefactor that Newcastle ever had. (His) statue now stands between the Hancock Museum and King's College (now Newcastle University) both of which owe so much to his public spirited munificence'. (Middlebrook, 1968, p. 310). Even at the time of the Royal visit, it was estimated that Armstrong's benefactions to Newcastle, in 25 years, had amounted to £150,000. (Newcastle Weekly Chronicle 10th May, 1884).

Meanwhile, on the second day of their visit, the Royal party had sailed from Newcastle's Corporation Quay, where Armstrong built his first cranes and launched his career as an industrialist. This occasion was the culmination of another of Armstrong's enterprises, the opening of a new dock at Coble Dene, near the mouth of the Tyne, to be named the Albert Edward Dock in honour of the Prince of Wales. The gates of the dock, operated by hydraulic power, had been made by Armstrong's firm at Elswick, which the Royal party subsequently toured. In addition to the many feats of engineering viewed that day, the local press observed that the Prince inspected one of Armstrong's earlier engineering marvels: 'that triumph of native engineering skill, the gigantic Swing Bridge which, although weighing 1,450 tons, is opened and shut by the touch of a finger'. (Newcastle Daily Chronicle 21st August, 1884).

The previous day, a banquet was held in honour of the Royal visitors when Joseph Cowan thus proposed the toast to the industries of Tyneside:

'No name can be more appositely associated with northern industry than that of the founder and master-mind of Elswick, who has cast his thoughts into iron, invested them with all the romance of mechanical art and achieved wealth almost beyond the dreams of avarice. But he does not live for himself alone. He is happy when others can share his bounty. Self-prompted and self-sustained and, as regards his present profession, self-taught, he has worked his way through a thousand obstacles and become one of the ornaments of his country, where his country is one of the ornaments of the world. He has interwoven the history of his life with the history of his native place, and has made one of the foundations of his fame the monument of his virtues. He has shown how the lofty aims of science and the eager demands of business can be assimilated. A man who has won renown in wider scenes feels, when his spirit wearies and his strength fails, that there is no admiration so acceptable, no applause so sweet as that which springs from those who have followed his career, sympathised with his struggles, and exulted in his triumphs. At such times and in such circumstances his heart warms to his own people and their hearts warm to him. There is this laudable reciprocity of sentiment between the citizens of Newcastle and Sir William Armstrong'. (Quoted in R. Cochrane, Great Thinkers and Workers, pp. 44-45).

To Cowan's plaudits, Armstrong modestly and succinctly replied:

"I should have felt more grateful to him had he toned down his remarks to the level of my merits!"

Nonetheless, in retrospect, Middlebrook thought otherwise.

'The high moral character of these leading men (Armstrong, Cowen et al), their passion for freedom, their belief in the value of education, and the ideals of social service and tolerance which inspired them, represent the finest aspect of the liberal tradition that was still running at full flood when the war of 1914 began'. (Middlebrook 1968, p. 311).

Among Armstrong's abiding interests was his membership of the Literary and Philosophical Society - an association which lasted some 64 years, including the Presidency from October 1859 until his death in December 1900. The Society recorded with gratitude that: 'It may justly be said that no one could be more closely and worthily connected with the history of the Literary and Philosophical Society than the late President who always looked upon it as an institution of the highest value, especially from an educational point of view'. (Lit & Phil 108th Annual Report). The Report listed the many occasions on which Armstrong had lectured to the Society over the years. From 1844 when he first lectured on hydo-electricity until, fifty one years later when he gave the centenary Lecture on "The Novel Effects of Electrical Discharge", he gave the Society the benefit of his research.

From this Report emerges evidence of the pioneering nature and extent of Armstrong's electrical research. Apart from his research into the production of electricity which, as noted earlier, was done contemporaneously with some of Faraday's own work and which led to Armstrong's admission to the Fellowship of the Royal Society, the Report notes that in 1846 he 'took a leading part' in the Society's activities and 'lectured on "The Principles and Operation of the Electric Telegraph"'. The benefit of this little known aspect of Armstrong's research was given to the Society within a decade of the patenting, by Wheatstone and Cooke, of the electric telegraph and shows the multiformity, not only of Armstrong's ability in general, but of his electrical research in particular.

The same Report refers to Armstrong's generosity to the Society and recalls not only his gift of a new lecture theatre but the donation which excelled that of all the other donations during the extension of the library premises. The expansion of the North Eastern Railway Company, already noted in connection with the other educational institutions on the site of Westmorland House, affected the Literary and Philosophical Society, albeit to a lesser extent. In 1885, the Railway Company served notice that they intended to purchase, under Parliamentary powers, the yard at the back of the Society's premises as part of the enlargement of the Central Station complex. (Spence Watson, p. 196). Fortunately, by mutual agreement, the Society acquired a nearby piece of land belonging to the Railway Company. This enabled the Society to build a fresh wing at right angles to their existing premises which 'added greatly to the permanent comfort and usefulness of the Institution'. The Railway

Company paid £55,000 for the transaction, Armstrong, 'with his wonted liberality, donated £700, while the remaining membership gave a total of £750'. (Lit & Phil 108th Annual Report).

That Report further indicated that the Society would miss Armstrong, 'not only as a liberal benefactor' but for his active support of the institution and for his 'words of encouragement and advice which ---- were greatly appreciated'. (Lit & Phil 108th Annual Report). One example of his deep concern for the traditions and welfare of the Society is shown in the 104th Report. A resolution passed at the Annual Meeting of February 1896 condoning the connection between the Society and the newly established Economic Society caused Armstrong to resign his Presidency because of what he described as "elements foreign to the objects of the Society". The affair which had been festering from the previous October came to a head with Armstrong's decision and was not settled until the following July. As with the Engineers' Strike for the Nine Hour Day, Armstrong's uncompromising attitude was patently evident in this case. A bundle of fading letters in the Society's archives shows Armstrong at his most unyielding - even at 85 years of age - and throws interesting light on the somewhat shadowy blandness of the Report.

The opening salvo came from Armstrong at Cragside, in a letter dated 4th October 1895 addressed to the two Secretaries of the Literary and Philosophical Society. In it Armstrong drew their attention to the paragraph from that morning's Newcastle Daily Journal that there 'opened on Wednesday evening the inaugural lecture of a Society that has just been formed in connection with the Literary and Philosophical Society for the study of the social question'. Armstrong requested verification of the statement and clarification of any connection between the two societies. (Letter dated 7th October 1895. Correspondence Armstrong and the Economic Society, in Literary and Philosophical Society's Archives, Accession Number 53262).

As President, Armstrong should not have had to read in the press of any affiliation of another organisation with the Literary and Philosophical Society. Nonetheless, without petulance or rancour, his legally trained incisive mind came straight to the knub of the argument in his reply to the Society's letter. He observed that: "The Economic Society is to have the use of our lecture room and that members are at liberty to attend on payment of the nominal sum of 1/- per year". This, he argued was tantamount to an affiliation of the Society with a political organisation. To the opening words of the inaugural lecture: 'The social question is in the air', he made the rejoinder that: "This gives the keynote to the whole business and expreses the very essence of politics". He underpinned his argument by indicating that he had "not the slightest objection to societies being formed for the discussion of the Social question or any similar question but I emphatically object to any such society being tacked on to (ours) which was formed for an entirely different purpose". (Letter dated 7th October 1895. Correspondence Armstrong and the Economic Society).

Although the two secretaries offered to meet with Armstrong, he declined their invitation but continued to argue his case against "introducing politics by a side window" and against the introduction of "controversial and inflammatory subjects under the guise of science". The ensuing correspondence, although protracted, was never acrimonious. Nonetheless, events reached their nadir when at the Annual Meeting of the Society in February 1896, the following resolution was carried:

'That this meeting, believing that the Economic Society is in accordance with the constitution of the Literary and Philosophical Society, desires that the connection between the two shall continue'. (Lit & Phil 104th Annual Report). This decision so outraged Armstrong that he resigned from his office of President.

Such a decision by someone of Armstrong's intellectual and social standing could not go unheeded. In consequence, the Society spared no effort to redress the balance. The first public intimation of an end to the fracas came in an account in the Newcastle Daily Chronicle of 5th May 1896. This indicated that a memorial, signed by 500 members of the Society, and an accompanying letter had been sent to Armstrong, asking him to withdraw his resignation. The letter suggested that his loss to the Society would be 'little short of calamity' and that he should 'retain the office which you have adorned so long'. In that event, 'the best interests of the Society will be promoted and served and you will add one more to the many benefits you have conferred on our century old "Lit. and Phil." whose welfare and security is our sole reason for thus approaching you'.

Thereupon Armstrong acknowledged the "flattering memorial" asking him to withdraw his resignation. This, he admitted, he would "cheerfully do if the obstacle were removed". The barrier was "the continued maintenance of a branch of our Society which, under the ambiguous title of the Economic Society has already, by its prospectus, proceedings and programmes proved that its scope extends to the discussion within our Society of political subjects even of the most contentious character. Its continuance, therefore, is a permanent violation of the fundamental rules of the Society which forbids the discussion of political subjects". When Armstrong originally objected, the Committee agreed to discontinue their connection with the Economic Society and announced their decision in the Annual Report. Nonetheless, according to Armstrong, the members present at the meeting "took the matter out of the hands of the Committee" and confirmed the original arrangements by a considerable majority. In the event, Armstrong declined "to countenance this state of things and until the adverse vote of the last meeting is rescinded, my attitude to the Society must remain unchanged". (Letter dated 3rd May 1896. Correspondence Armstrong and the Economic Society).

In order to resolve the impasse, a special meeting of the Society was convened on 9th July 1896 when the following resolutions were passed:

1. That the connection existing between the Economic Society and the Literary and Philosophical Society shall now cease.
2. That this meeting of members respectfully requests the Rt. Hon. Lord Armstrong, C.B. to reconsider his decision to withdraw from the Presidency of the Society.
3. That a copy of the resloutions passed at this meeting be forwarded to Lord Armstrong. (Lit & Phil 104th Annual Report).

In a reply from his new home at Bamburgh Castle, on the Northumberland coast, Armstrong was obviously impressed by the weight of support for his return to the office of President. He agreed to do so, confident that a majority of the Society would "always be found to help close the door against the admission of subjects notoriously tending to discord". That being stated, he indicated that he would not object if the Economic Society met on the premises of the Literary and Philsophical Society provided that it was quite apparent that they were operating as two independent organisations. (Letter dated 11th July 1896. Correspondence Armstrong and the Economic Society).

For their part, the Economic Society expressed gratitude for 'such an act of grace' and indicated that, given the proposed conditions, the members 'should esteem the privilege very highly and should (make every effort) to retain the goodwill of your Committee and members'. (Letter dated 14th July 1896. Correspondence Armstrong and the Economic Society). Consenting to Armstrong's request that his letter be made public, the Committee were 'glad to report' that he had resumed the Presidency. This action brought to an amicable conclusion a unique altercation between the Society and one of its most distinguished members.

But Armstrong was not merely engaged in protracted correspondence on contenious issues. Apart from buying the historic Bamburgh Castle from the trustees of Lord Crewe, Bishop of Durham, and making it one of Britain's most impressive fortresses, he was engaged in serious scientific research. This, he admitted, was more conducive to the elderly Armstrong than the cut and thrust of politics or public and business life. In 1897, his researches formed the basis of a standard work <u>Electric Movement in Air and Water</u>, which was beautifully illustrated by John Worsnop of Rothbury. Two years later, when almost ninety years of age, he worked with Dr Henry Stroud, Professor of Physics at Durham University College of Science, to produce an even more lavishly illustrated supplement on his researches into sudden electrical discharge. This, according to the Principal of the Durham College of Science, was widely acclaimed as being his most important publication. (Gurney, 1901, p. 185).

An obituary tribute describes Armstrong as 'an enthusiastic worker in the more recondite branches of physical research', but adds that 'much of his investigation in this field is unknown beyond a very narrow circle'. The article uses Armstrong's own words to describe one of the most interesting of his experiments which, begun half a century earlier, was only completed and brought to public attention in 1897:

"More than 50 years ago, when using my large hydro-electric machine before it went to the Polytechnic Institute, I hit upon a remarkable experiment. Taking two glasses filled to the brim with chemically pure water, I connected them by a cotton thread coiled up in one glass, and having its shorter end dipped in the other. The two glasses were joined up to a machine, the one containing the coil of thread by a negative wire, and the other by a positive connection. On putting the machine into full action, the coiled thread was rapidly drawn out of the negative vessel and deposited in the positive one, leaving for a few moments a rope of water about 0.3 inches in length suspended between the lips of the two glasses. The experiment was made with the machine in the open air, and its highest power was required for producing the effect.

The experiment presents strong evidence of two currents flowing simultaneously in opposite directions, the negative inside the positive". (Anon, "Lord Armstrong", Engineering, Vol. 71, January 1901, p. 22).

These experiments led Armstrong to the conclusion that: "There can be no such thing as motionless electricity, the term 'statical' only implies bondage and absence of current".

Armstrong's researches have been described by modern scientists as 'very fine examples and reflect careful and painstaking work. As illustrations of electrical surface discharge ---- they have considerable illustrative and educational value'. (Quoted in McKenzie p. 114).

In 1897, Armstrong donated another £1,000 to the Durham College of Science, together with some of the valuable electrical apparatus used in his electrical experiments at Cragside. This includeed his Wimshurst Machine with such components as its electrometer, storage batteries and condensers, two large Ruhmkorff induction coils and 'his excellent electric lantern and microscopes'. In recording their gratitude, the College Council noted that: 'The apparatus will have value far beyond its intrinsic worth as coming from a Member of Council who has been closely connected with the College from its beginning, to whose genius Newcastle owes so much and who has won so remarkable a place in the history of Electrical discovery'. (Minutes Durham College of Science, 15th November 1897). The following year, it was agreed to seek Armstrong's approval in naming one of the laboratories in the Physics department 'the Armstrong Electrical Laboratory', in his honour.

(Minutes Durham College of Science, 21st November 1898). Meanwhile, in 1882, Armstrong had the received the D. C. L. from Durham University.

At the Centenary Lecture of the Literary and Philosphical Society, Armstrong gave his own account of his research:

"The Hydro-electric machine was my first love, but soon after its introduction, I became engaged in the hydraulic experiments which led to the establishment of Elswick, and from that time, to very recent years, the exigencies of business prevented me giving attention to electrical subjects; but I remained faithful to my first love and resolved to renew my addresses if ever circumstances permitted me to do so. This I did about a year ago, but in the meantime I had grown old and unable to bear the necessary outdoor exposure, so I transferred my affections to a less exacting mistress that would be satisfied with indoor attentions. That second mistress was the Rhumkorff induction coil. My first endeavour was to combine induction coils in such a manner as to form a battery. There were many impediments to this, and although I did not wholly overcome them, I succeeded in making a very powerful apparatus upon this principle". (Lit & Phil Centenary Lecture, 1893, p. 2)

The results of Armstrong's researches, especially the so-called 'Armstrong Effect' are still the legitimate concern of modern scholars, almost a century and a half later. As recently as 1976, Dr A.F. Anderson of the Research and Development Laboratories of N.E.I. Parsons and Co. Ltd., Newcastle upon Tyne, lectured on the subject, and its modern application. As he observed:

'Whilst the hydro-electric generator itself lies behind a glass case in the museum, the Armstrong Effect continues to prowl the earth and is a greater nuisance than it has ever been. The frictional electricity generated by steam escaping from fractured steam pipes, or by a burst aerosol can, or by moving dust is often sufficient to generate incendive sparks which can ignite gases and set off explosions. Bearings are sometimes damaged in large low pressure turbines, where steam is very wet, by static electric charge if precautions are not taken to earth the shaft'. (A.F. Anderson, "The Armstrong Hydroelectric Generator", Proceedings of the Institution of Electrical Engineers, History of Engineering Weekend Meeting, 2nd - 4th July, 1976, p. 55).

Dr Anderson then gave three modern examples of this phenomenon, of which the first actually changed the course of history. In 1942, the German Field Marshal, Rommel, had to halt his troops during his rapid advance towards Libya, because of explosions occurring in his tanks. This was thought to be due to mines, until it was discovered that the fine wind-blown sand was causing a build-up of static electric charge which was suddenly discharged when the tanks reached a patch of slightly greater conductivity and the resultant spark caused the explosion. Although the remedy was simply to earth the tank by a length of chain, the delay cost Rommel the desert campaign.

More recently, the increasing interest in electrostatics has resulted in the 'Armstrong Effect' being applied in some electronic spray guns when the paint droplets are highly charged by friction as they emerge from the spray nozzle. The resultant paint savings of as much as 75% makes them as much an economic business proposition as a scientific advancement. In his third example, Anderson regrets that, despite Armstrong's earlier research, too little is yet known about the electrostatic effects of moving particles, with the result that, in December 1969, three large oil tankers were severely damaged through explosions in their cargo tanks. While the tanks in all three ships were being washed out with high pressure water jets, the frictional charge thus generated was sufficient to cause the explosions. As Anderson aptly notes: 'How easy it is for a body of fundamental knowledge to disappear. Had the shipowners known of the Armstrong Effect, no doubt they would have used different procedures and avoided the danger'. Thus, he concluded, 'Even the events in an obscure Northumberland Colliery long ago may be relevant today'. (Anderson, p.56).

Dr Anderson's summary could be seen as a just appraisal of Armstrong's contribution to Science and Education. In a life which successfully embraced several careers Armstrong, in his speeches and in his research, proved himself to be a man of our time rather than of the Victorian era which, to many, he so aptly epitomised.

By providing schools and a Mechanics' Institute at Elswick, as well as by supporting the Literary and Philosophical Society, the Natural History Society, the Mining Institute and the College of Physical Science, he enabled ambitious working men to reach educational and social heights which, at that time, were attainable only by the privileged few. In his visionary speeches on such subjects as the economical use of fuel; the duration of our coal supplies; the harnessing of the sun's rays and of the world's mighty waterfalls in the generation of electricity; in his desire to see a uniform metrication system as well as a Channel Tunnel; in his support of self-help and enterprising initiatives, he was already preparing for "the immensity which lies beyond" - for the united Europe of the 1990s and the twenty first century.

It is during his last public lecture, and nearing the end of his long and successful life that Armstrong appears, not as the business tycoon; not as the armaments manufacturer or even as the scientist, but as the true educator.

By now, approaching ninety years of age, with Elswick and his own reputation well established, the strictures of the balance sheet or even the fear of industrial espionage or character assassination, were of little consequence to him. Now he could view life in general, or Science and Education in particular, in their true perspective.

When giving the results of his latest electrical research to the Literary and Philsophical Society he observed that:

"There will be some amongst you who will ask: 'Of what use are such experiments as these?' The answer is that the more we pry into the mysteries of electricity the more we shall be able to apply it to the service of mankind, but apart from that consideration, knowledge, for knowledge sake, is a worthy subject of pursuit". (Lit & Phil Centenary Lecture, 1893 p. 16).

APPENDIX I.

THE CURRICULUM FOR GREENHOW'S PROPOSED COLLEGE OF SCIENCE, IN NEWCASTLE.

(Greenhow Papers. Tracts, Volume 48 Number 8. In Newcastle upon Tyne Literary and Philosophical Society Archives).

At a meeting of the Literary and Philosophical Society, in Newcastle upon Tyne, on the 7th June, 1831, Greenhow suggested the following curriculum:

1. Latin and Greek Classics.
2. Mathematics and Mechanics.
3. Logic and Mental Philosophy.
4. History, Ancient and Modern.
5. Political Economy.
6. English Law, Ethics and Jurisprudence.
7. Natural History, Zoology and Comparative Anatomy.
8. Chemistry, Mineralogy and Geology.
9. Botany and the Physiology of Plants.

The two latter were to constitute part of the course of medical study, which would include:

1. Anatomy and Physiology.
2. Principles and Practice of Surgery.
3. Principles and Practice of Medicine.
4. Materia Medica and Pharmacy.
5. Midwifery and Diseases of Women and Children.
6. Clinical Lectures in Surgery and Medicine.

APPENDIX II.

COPY OF LETTER FROM W. G. ARMSTRONG, READ BY THE TOWN CLERK TO THE FINANCE COMMITTEE OF NEWCASTLE UPON TYNE, 14th JANUARY, 1846.

(E.W.L.M.I. Papers. In Tyne and Wear Archives, Newcastle upon Tyne).

Newcastle, 24th November, 1845.

To the Finance Committee of the Town Council,

of Newcastle-on-Tyne.

Gentlemen,

I beg to draw your attention to a plan I have matured for applying the pressure of water in the streets' pipes in the lower parts of Newcastle, to the working of cranes upon the Quay, with the view of increasing the rapidity and lessening the expense of the operation of delivering ships.

It will readily be perceived that whatever has a tendency to accelerate the unloading of ships at the Quay must not only be highly advantageous to the shipowners and merchants of the port, but must also have the effect of increasing the accommodation to shipping which the Quay is now capable of affording.

A working model has been constructed for the purpose of illustrating the operation of a crane upon the proposed plan; and I am fully persuaded, after careful investigation of the subject, that the advantages to which I have adverted would be realised by such a method of lifting goods.

In order to relieve the Corporation from the speculative outlet of making the experiment upon a large scale, a few of my friends are willing to join me in the risk and expense of adapting the plan to one of the existing cranes; provided that the experiment should prove successful a lease be granted to us of all the cranes upon the Quay belonging to the Corporation for the period of ten years, at the present rate, and upon the following terms and conditions.

1st. That we shall be at liberty to apply the hydraulic principle to all the existing cranes, and shall have the exclusive right of erecting others on the same principle upon the Quay in situations to be approved of by the Corporation or their authorised agent.

2nd. That we shall be bound to reduce the present rates of cranage to the extent of at least 20%.

3rd. That the Corporation shall take the machinery at a valuation at the end of the term.

We will also engage, in case the experiment should fail, to restore the crane to be operated upon to its present state, if required.

Should you think proper to accede to this proposition and the result of the trial should be favourable, the public and the port will reap the immediate advantage of the improved system, and the Corporation will eventually come into the receipt of an increased revenue, without sustaining any loss in the meantime.

I am, Gentlemen,

Your very obedient servant,

(Signed) W. G. Armstrong.

APPENDIX III.

RULES OF THE ELSWICK ENGINE WORKS' LITERARY AND MECHANICS' INSTITUTE.
ESTABLISHED DECEMBER 1848.
PUBLISHED 1859.

(E.W.L.M.I. Papers. In Tyne and Wear Archives, Newcastle upon Tyne).

RULE I.

That this Institute be called THE ELSWICK ENGINE WORKS' LITERARY AND MECHANICS' INSTITUTE.

RULE II.

That its object be the advancement of its members in the Arts, Science and General Literature by means of Lectures, Conversaziones and Classes. That classes be established for Reading, Writing, Grammar, Arithmetic, Mensuration, Geometry, Algebra and Trigonometry; also Mechanical, Architectural and Ornamental Drawing; Hydraulics, Hydrostatics and Pneumatics; Geography, History, Phonography, Elocution etc.

RULE III.

That the affairs of the Institute be conducted by a committee of fourteen members, which number shall include the President, Treasurer, Librarian, Secretary and Secretary's Assistant. No member under 18 years of age to be on the committee.

RULE IV.

That general meetings of the members of the Institute be held on Monday in the first week of April and Monday in the last week in September, to receive the Treasurer's accounts and a full report from the Secretary of the proceedings of the Committee for the previous half year and for the election of officers.

RULE V.

That the officers and committee be chosen at a general meeting of the members. The Secretary shall take down the names of such as may be nominated and shall make a separate list for each office. Each member to set his mark opposite the name of the nominee whom he may deem most suitable to fill the respective offices. The persons opposite whose names the marks are placed shall be duly elected.

RULE VI.

That no one shall be appointed to the offices of President, Treasurer, Secretary or Librarian until he shall have been a member of the Institute for twelve months, or of Committeeman until he shall have been a member for six months. That the President, Librarian and Secretary's Assistant and four members of Committee be elected at the September Meeting. The Librarian, at the time of his appointment, to choose his assistant, subject to the approval of the meeting. The Committee to meet on the first Monday in each month at eight o'clock in the evening.

RULE VII.

Any person wishing to become a member of the Institute shall state such a wish to any one who is a member of the Committee, who shall inform that body at their first meeting when, if the applicant be of good moral character, it shall be lawful for the Committee to elect him at the same meeting.

RULE VIII.

That the sons of men employed in the works be admitted on application by their parents at the age of twelve years. Persons not employed in the Works to be admitted at the age of fourteen years.

RULE IX.

That the contribution for adult members be three pence per fortnight, and for minor members three halfpence per fortnight. All contributions to be paid in advance to the Secretary or his assistant, one of whom will attend in one of the rooms of the Institute every alternate Friday evening between the hours of seven and nine for the purpose of collecting them. Any member falling in arrears and objecting to pay his contribution when applied to by the Secretary to be excluded.

RULE X.

If a member leave the locality of the Institute for more than a fortnight, his contributions may be suspended for any time beyond that period. On his return, he shall be entitled to his membership on paying his fortnight's arrears.

RULE XI.

The Librarian shall be present from 7 till 9 on Friday evening of each week for the reception and delivery of books; two weeks allowed for reading each book. If kept longer than this period, a fine of two pence will be levied for every week's detention. Any member injuring or losing a book shall pay what the Committee may deem adequate to the said injury or loss, or be excluded. Any member lending a book to any other member or to any person or persons not members of this Institute, excepting his own family living in the same house with him, shall be subject to a fine of one shilling. The fines to be paid to the library.

RULE XII.

A book shall be kept by the Librarian in which he shall register by whom and when books are taken out, and by what time they are returned. No member, on returning a book, shall take out the same again, if applied for by another member on the same evening, neither shall any book be transferred from one member to another. Personal application for books to precede applications by proxy.

RULE XIII.

Any member may propose a book for the Library, the proposition to be in writing, stating title, price and by whom published. Such a proposition to hang in the reading room to receive the signatures of others who may be desirous of the same, two weeks previous to its being laid before the Committee for its acceptance or rejection. That all 'novels' be subject to the approval of a general meeting, and that a week's notice be given of the calling of such a meeting.

RULE XIV.

That each head teacher may choose what number of assistants he may deem necessary to carry on the business of his class, and who may pursue what system of teaching he may think best.

RULE XV.

Pupils can purchase of the Institute books, instruments, drawing paper etc. by applying to the teachers of the classes.

RULE XVI.

The classes shall commence about the middle of September, and shall be continued for six months, ceasing about the middle of March.

RULE XVII.

A donation of the value of £5 or more in cash or books shall entitle the donor to become an honorary member of this Institute.

RULE XVIII.

That no smoking be allowed in the rooms of the Institute.

RULE XIX.

That the library be insured against fire, to such an amount as the Committee, for the time being, may think proper.

RULE XX.

That the property of the Institute be vested in the members, so long as there are to be found fourteen willing to continue their subscriptions. Should there not be this number, the books and all other property belonging to the Institute shall be vested in the firm of Sir W. G. Armstrong and Co., or their successors, who shall act as trustees for the same until fourteen are found willing to govern the working of the Institute as stated by Rule III, and that so long as eight persons are willing to continue their subscriptions the trustees shall appoint one of them as Librarian, who shall act as appointed by Rules XI and XII.

Bye Law.

Pupils attending the classes who are not members of the Institute, to pay a quarter in advance.

April 1859.

APPENDIX IV.

SPEECHES OF SIR W. G. ARMSTRONG, 1ST SEPTEMBER, 1862.

(E.W.L.M.I. Papers. In Tyne and Wear Archives, Newcastle upon Tyne).

A. AT THE LAYING OF THE FOUNDATION STONE OF THE NEW BUILDING OF THE ELSWICK WORKS' MECHANICS' INSTITUTE.

"I have great pleasure in accepting your invitation. As your address truly says, I take great interest in the affairs of this institution, connected as it is with the two establishments which I have been chiefly instrumental in establishing here, and I most earnestly hope that the building of which the foundation stone is laid this day will realise all the expectations that we entertain respecting it. The Companies who bear the expense of the building will have done their part in the good work, and the remainder will rest with you, whose duty it will be to make the institution as beneficial as possible for the neighbourhood".

B. AT THE SOIREE AND PRIZE GIVING WHICH FOLLOWED.

After indicating his pleasure at being asked to preside at the Annual Meeting, Sir William spoke of the "importance, dignity and usefulness of the Institution at Elswick".

"The Society", he continued, " has been in operation for 14 years, and I believe that no other such institution has done more good. it has passed through a period of vigorous boyhood and now, I trust, it will enter on an equally vigorous period of mature manhood.

The good which institutions of this nature are calculated to do in supplying the deficiencies of an imperfect education and in offering the means of intellectual cultivation are incalculable. There is no difference in intellectual power between the working man and those who are placed in a higher sphere. The only difference is in the amount of knowledge and mental cultivation possessed by each.

Mechanics' Institutes, in supplying the means of acquiring knowledge and of cultivating the mind, afford to all humbler classes the means of advancing their condition, or at all events, whether successful in doing so or not, they tend to make them more respectable and happier men.

Although the working man has not the lever to cultivate his mind possessed by the wealthier man, he yet, with industry and ability, may cultivate himself. With the assistance of the Mechanics' Institutes and with the advantage of the intelligent society he will meet there, he may succeed in improving himself to a very great extent. I sincerely hope that the new building with its improved facilities and greater comfort will tend to increase the benefits of the present institution. I trust that the members will increase and that we will reap the advantage, morally and in every respect, in this now populous neighbourhood".

APPENDIX V.

SPEECH OF SIR W. G. ARMSTRONG AT THE OPENING OF THE ELSWICK ENGINE WORKS' LITERARY AND MECHANICS' INSTITUTE, 22ND SEPTEMBER 1863.

(E.W.L.M.I. Papers. In Tyne and Wear Archives, Newcastle upon Tyne).

"It is now 15 years since the Institute commenced. I believe that Mr John Windlow, one of the principal foremen in Elswick Works had the credit of being the founder. Members to the number of twenty met in the first instance at Mr Windlow's house for the laudable object of mutual improvement. Soon afterwards a room was provided by the Elswick Company, which now provides this commodious building in which we are now assembled. Since the commencement of the Institute, a library has been in the course of formation and now numbers about two thousand volumes. But the greatest feature of interest is the classes maintained from the first for the instruction of boys and men. I need adduce no further proof of the success of the classes than to point to the fact that out of thirty seven persons employed as draughtsmen, men and boys, in the drawing office of Elswick Works, no less than thirty three have been advanced from the workshops, and have derived their qualifications from classes supported by this Institute.

So far as the classes are concerned, the success of the Institute is complete, but with regard to mere reading members, those who availed themselves of the advantages of the institution are not so great as one would have a right to expect.

I fear that it must be admitted that attempts which have been made to popularise science by means of the Mechanics' Institutes have not been highly successful. The reason probably is that to acquire science is not amusement but positive work. It requires mental labour and it is perhaps too much to expect that men who are required to work hard with their hands should at the same time work hard with their heads. At the same time, there are individuals who are determined to get on in the world under all discouragements and to acquire the knowledge necessary for that purpose, and if it were only to lend a helping hand to those individuals, few though they be, it would be quite worth while to have institutions of this nature. But it is not necessary or even desirable, that Mechanics' Institutes should be founded upon purely scientific grounds. A great object will be attained if salutary amusement for leisure hours were afforded to working men. They require good and wholesome recreation both of body and mind. In summer they should seek recreation in the open air in their gardens if they have them, and if not, in the open fields. But in winter it is highly desirable that they should seek amusement in well selected literature, however light it may be. It is by means of books that working men can bring themselves into communion with the highly gifted cultivated minds, and they will derive instruction, refinement and amusement from doing so. It is in an institution like this, where a working man, surrounded by books of the best authors and in communication with the most respectable and most intellectual men of their own class can best acquire those qualifications which will increase his happiness and exalt his nature. The Elswick Company, impressed with these views and anxious to promote the mental cultivation and intellectual enjoyment of their workmen, have provided this spacious and convenient building, and I most sincerely hope that it will have the effect of inducing large numbers to avail themselves of the advantages presented to them, and I trust that it will form the commencement of a new era in the history of this institution".

APPENDIX VI.

DOCUMENTS RELATING TO PROPOSED BRITISH COLLEGE OF PRACTICAL MINING AND MANUFACTURING SCIENCE.
(In Newcastle upon Tyne University Library).

(Transactions N.E.I.M.E. Vol. IV, 1855-6 p. 108-109).
Letters between Mining Institute and Duke of Northumberland.

North of England Institute of Mining Engineers,
Newcastle upon Tyne, 24th December, 1855.

My Lord Duke,

I am desired respectfully to request your Grace's favourable consideration of the accompanying prospectus and circular emanating from the Committee appointed to take the requisite steps for establishing a College of Practical Mining and Manufacturing Science at Newcastle upon Tyne.

The want of an Institution of this practical character is greatly felt, its object being, by bringing the resources of Science to bear upon Mining Operations, to economise the cost of production, and also to diminish the causes of the loss of life from explosions of fire-damp and other casualties, which have hitherto rendered Mining so destructive an occupation.

It is expected that the aid of the Government will be procured towards the establishment of the proposed College, providing sufficient general support can be first obtained towards raising the estimated sum of £35,000.

After duly weighing all the circumstances it appears to the Committee that the success of this most desirable project may be regarded as depending on the subscriptions of the Lessors and Lessees of Mines, especially upon those of individuals high in position, who possess a permanent interest in the mineral resources of the country, and to whom this circular and accompanying prospectuses are therefore addressed, before distribution among the public at large.

To your Grace, in particular, it is, for the reasons given, deemed right to make a first application, whilst your Grace's name at the head of the subscription list would, at the same time, materially assist in the raising of the requisite funds, and by initiating the undertaking confer the essential benefit of placing it in a proper position before the public.

And we beg to add, that it would likewise confer an additional benefit to the undertaking, and a great stimulus to its success and efficiency, if your Grace would kindly please to become the Patron of the College.

Awaiting the honour of your Grace's reply,
I am, my Lord Duke,
Your Grace's very faithful and obedient servant,
Nicholas Wood, (Chairman).

Alnwick Castle, 11th January, 1856.

Dear Sir,

I am desired by the Duke of Northumberland to acknowledge the receipt of your letter of the 10th inst., forwarding his Grace the prospectus of a proposed College of Practical Mining and Manufacturing Science to be established at Newcastle upon Tyne, of which his Grace is asked to become Patron, soliciting also his Grace's aid towards the establishment of the Institution in question.

The Duke has been for some time aware of the intention of the promoters to establish an Institution of the character described, and directs me to thank the Committee for their attention in presenting him with the documents above mentioned.

His Grace is of opinion that the projected College, if properly established and conducted, is calculated to prove highly advantageous to the Mining Interests of this part of the country, as well as to those of the kingdom at large, and the project has, therefore, his entire and hearty concurrence.

The Duke is aware, from experience, that the permanency of such institutions greatly depends upon the endowment being adequate to carry them properly forward; especially as regards the procurement of suitable and talented Professors, and therefore recommends this subject to the chief and earliest consideration of the Committee.

Entertaining this view, his Grace directs me to state that if £15,000 be raised for the endowment, he will contribute £5,000 making £20,000, and if £30,000 be raised, he will subscribe £10,000, making £40,000 for the like purpose.

The Duke also accepts the honour of becoming Patron of the College, in compliance with the request of the promoters.

As regards the particular locality of the proposed College, and the expediency or otherwise of appending it to, or connecting it with, any existing establishment; the Duke would recommend that these subjects should receive most mature and dispassionate consideration, as the success and permanency of the intended Institution may greatly depend upon the decision.

I am, dear Sir,
Your very faithful servant,
Hugh Taylor.

(Transactions N.E.I.M.E. Vol. VI, 1857-8 p. 201-202).
Correspondence between Temple Chevallier and Nicholas Wood

College, Durham, Dec. 15, 1857.

Dear Sir,

The Warden and Senate desire me to inform you that the University of Durham is ready to give its best attention and exertions, as far as its means extend, for furthering the objects proposed by the Committee for Mining Education.

It appears to the Warden and Senate, that the regulations of the University now in force for Students in Mining and Civil Engineering, may, without inconvenience, be so modified as to be adapted to the contemplated scheme.

A Committee of which the Warden and I are members, has been appointed to confer with your Committee whenever it be convenient to you.

I remain, Dear Sir,
Yours, most faithfully,
Temple Chevallier.
Registrar.

Durham, Feb. 10, 1858.

My Dear Sir,

I am glad to learn from the Warden, that your health is so far re-established as to induce you to hope to be present at the meeting soon to take place at Newcastle, with the view of forming, among other matters, a connection between those interested in the Education of the Mining and Engineering Classes, and the University of Durham.

The University is quite ready cordially to co-operate in such a work, by any means not inconsistent with its own primary institutions. And I think, there would be no difficulty in making an arrangement, by which a College, subject to its own independent government, should give to the University and receive from it, advantageous support.

There would probably be in such a College, a number of students who would not require the kind of instruction which a University could more properly supply; and those students might be entirely under the care and instruction of the officers of the College. Others would be sufficiently advanced to avail themselves of the lectures and general studies of the University; and those students might be matriculated as members of the University, and pursue the studies to such an extent as appeared desirable and practicable.

If it were a part of the scheme to erect a College, and the University possesses property available for that purpose, there would be every disposition to facilitate the arrangements necessary for such a scheme.

If you would wish for any more definite information respecting the University, which I might be able to supply, I shall be happy to answer any enquiries; or if you deemed it more satisfactory, I would call upon you any day that you would appoint, if you will tell me the most convenient train by which I may reach you.

Believe me,
My dear Sir,
Yours very truly,
Temple Chevallier.

(<u>Transactions N.E.I.M.E.</u> Vol. VII, 1858-9 pp. 171-174).

A Report of the Committee of the North of England Institute of Mining Engineers on the Establishment of a Mining College connected with the University of Durham.

Mining Institute Rooms, May 20th 1859.

The Committee for the establishment of a Mining College have to report that, in pursuance with the course agreed to be adopted, they have very fully brought the subject before the Coal Trade of Durham and Northumberland, as well as that of the kingdom at large.

While several lessors and lessees of mines have liberally offered their support to the proposed measure, it must be admitted that the amount of encouragement received by the committee does not offer, on the whole, a prospect of the successful erection and endowment of so desirable an institution in a separate form.

Under these circumstances the committee, anxious to carry out the object for which they were appointed, and acting under the authority and with the advice of the Mining Institute, to whom the various proceedings have from time to time been fully explained, have endeavoured to realise by means of an existing establishment those great objects which they doubt not will be fully appreciated by the Mining interest as soon as their practical and economical results in the improvement of Mining operations, and also in diminishing the waste of life, come to be understood and developed. The Institution referred to is the University of Durham, the authorities of whom have shewn great willingness to meet the views of the Committee.

In several interviews which have been held with them, the following heads for the establishment of a Mining College within the precincts of the University have been provisionally arranged:-

Durham, February 15, 1859.

Heads of a provisional arrangement for the establishment of a Mining and Engineering College, as agreed to by the Warden and Senate of the University of Durham.

1. A College of Mining and Engineering shall be established at Durham, in connection with the University of Durham.

2,. The College shall be managed by a council, consisting of a Principal, the Professors who give Lectures in this department, and a number of persons not exceeding three, nominated by the subscribers towards the funds of the Insitution.

3. The University of Durham shall provide two Professors namely:-

- i. The Professor of Mathematics.
- ii. A Professor of Natural Philosophy and Applied Mechanics.

The Mining and Engineering College shall provide three Professors

- i. Of Mineralogy, Geology and Working Mines
- ii. Of Chemistry
- iii. Of Plan Drawing, Levelling, Surveying and Practical Engineering.

All Professors shall be Officers both of the University and of the Mining and Engineering College.

4. The Principal shall be nominated by the Mining College, and approved by Convocation.

5. The Principal shall be charged with the superintendence of the students, unless they are members of some College or House in the University.

6. Lecture Rooms shall be provided by the University for the five Professors. Chemical Laboratories and Workshops shall be provided by the Mining and Engineering College.

7. Students in Mining and Civil Engineering shall be of two classes, matriculated and non-matriculated; matriculated students shall reside in some College, Hall or House licensed for that purpose by the University.

8. Matriculated students shall be admissible to the academical rank of Mining Engineer or Civil Engineer according to the regulations passed in January, 1855.

9. Instruction shall be provided for increasing the usefulness of Schoolmasters in the Mining Districts.

10. Arrangements shall be made for enabling the students to inspect Mines and obtain instruction in practical work.

11. All non-matriculated students shall be subject to such discipline as shall be determined by the University and the Mining and Engineering College.

12. Every matriculated student shall pay an admission fee of £2, and a terminal fee of £5. The admission fee shall be divided equally between the University and the Mining and Engineering College. The terminal fee shall be divided, two fifths to the University, and three fifths to the Mining and Engineering College.
13. The fees received either by the University or by the Mining and Engineering College shall be applied partly to the payment of the Lecturer, and partly to general purposes connected with Civil Engineering and Mining.

APPENDIX VII.

Letter from Professor Temple Chevallier, Registrar of Durham University, to South Shields Committee. Undated but following their meeting 24th February 1841.

(Report from Select Committee on Coal Mines, 1852, Appendix IV, pp. 200 - 201).

(In Newcastle upon Tyne University Library).

'In consequence of the wish you expressed at your late conference with the Warden and Senate, to be informed how far the course of education for students in civil engineering and mining in the University of Durham is capable of being extended, so as to be available for the objects which you have in view, I have the honour to send you a brief statement of that course of study.

The class of students in civil engineering and mining was opened in January 1838. The full course of study occupies three years; but certificates of competency, in particular subjects, may be obtained after a shorter time. The following are the subjects included in the course of study:-

Arithmetic,
Algebra,
Euclid,
Logarithms,
Plain Trigonometry,
Solid Geometry,
Analytical Geometry,
Theoretical and Practical Mechanics,
Differential and Integral Calculus,
Dynamics,
Hydrostatics and Hydraulics,
Spherical Trigonometry and Astronomy,
Surveying, Levelling and the Use of Instruments,
Pneumatics,
Practical Mapping and Architectural Drawing,
Theory of Perspective and Projection,
Hydrostatical and Hydraulic Instruments in general,
The Steam Engine,
Optical Instruments,
Theoretical and Practical Chemistry,
Theory of Heat,
Mineralogy,
Metallurgy,
Geology,
The French, Italian and Spanish Languages.

The progress of the students is tested by annual public examination; and the extent to which the several studies are pursued will be best understood by reference to the examination papers set at the final examination of 1840, printed in the Appendix to the Durham University Calendar for 1841. By the regulations of the University, Title VII, "persons who are not members of the University are admissible, with the approbation of the Warden, to attend any course of public lectures".

In addition to the theoretical instruction, the students are constantly engaged in the practical drawing of plans and machinery, and in levelling and surveying under the superintendence of a competent instructor. They avail themselves of the facilities afforded by their neighbourhood, to obtain an insight into the modes of working coal pits, and to conduct underground surveying. They visit also, under proper inspection, the principal public works, manfactures of machinery, iron works etc. in the vicinity, and are required on such occasions to deliver written reports.

Proficiency in those branches of practical work is encouraged by prizes devoted to that particular purpose. It will thus be seen that the course of study already established for students in civil engineering and mining, requires but little modification and extension in order to meet the views of the Committee for the investigation of accidents in mines. The principal addition required appears to be a professorship of practical engineering and mining with an endowment sufficient to ensure the services of a person of experience and high scientific character.

The University of Durham, by having been the first academical body to establish a class of civil engineering and mining, has given full proof of its anxiety to supply an acknowledged deficiency in the system of general education, and is still willing to co-operate further in order to effect an extension of its plans'.

APPENDIX VIII.

Reply to the Royal Commission on Technical Instruction from Sir W. G. Armstrong, Mitchell and Company, Elswick Works, 20th February 1883.
(Samuelson Report, Vol. XXI, Appendix G, pp. 646-651).

(In National Library of Scotland, Edinburgh).

Gentlemen,

We have the honour to ackowledge your circular of the 8th inst.

The technical instruction given in the institution attached to these works and in similar institutions throughout the district has undoubtedly a beneficial influence on the industries in the locality.

We enclose a syllabus of the classes at the Elswick Mechanics' Institute.

Two hundred and sixty pupils attend these classes, 160 of whom belong to our works, chiefly apprentices; the remainder of the students belong to works of a similar character in the neighbourhood

Our experience of these classes is that they not only develope thought and intelligence, but they also tend to foster studious and steady habits and to raise the tone of the students; we find as a rule, that the students who are most regular in their attendance and most earnest in their endeavours to benefit by the instruction, turn out to be the most efficient workmen, and are those we are most anxious to retain with the view of making them foremen, and ultimately placing them in higher positions. We recruit our drawing office from the apprentices at the works who have attended these classes and shown intelligence.

As regards your second inquiry, it is our constant endeavour to make the classes as useful as possible, and we gladly avail ourselves of anything which experience teaches us will tend to this result.

The tendency which is becoming more and more marked in the direction of increasing not only the difficulty of the examination in individual subjects but also increasing the range of subjects in all competitive examinations, is, we consider, an evil which should be carefully guarded against; for while offering a strong inducement to those who happen to possess exceptional powers of being crammed, it deters many who, although equally intelligent and equally gifted with all the qualities which combine to make the highest class of usefully intelligent men, are deterred from a feeling of inferiority in their powers of reception from entering into the competition.

It does not always follow that those gifted with the power of absorbing a larger amount of information preparatory to an examination are the most practically useful in after life, and even were this the case, it is obvious that more general benefit will result from a larger number of students thoroughly well grounded than a few brilliant ones obtained at the cost of deterring others from competing.

We are, etc.

A detailed prospectus was appended, showing the organisation of the classes and the curriculum at the Elswick Mechanics' Institute.

The main subjects included:
Mathematics, Drawing, Mechanics, Physics, Inorganic Chemistry, the Manufacture of Iron and Steel, Mechanical Engineering, (City and Guilds of London Institute), Navigation and Nautical Astronomy, Freehand Drawing and Shorthand.

APPENDIX IX.

Armstrong's views on Technical Education. In the letter from Newcastle, dated 31st October 1877, to the Committee on Technical Education of the Livery Companies of London.

(Livery Companies of London Committee. Report on Technical Education, 1878).

(In Library of the City and Guilds of London Institute).

"I should recommend the Livery Companies, in carrying out their very laudable project of devoting a portion of their funds to the promotion of Technical Education, to aim at effecting a wide diffusion of scientific knowledge in an elementary form, rather than the adavancement of the pupils to very high attainment. I do not in the least disparage high class education in science, but the persons requiring it are comparatively few, and are for the most part competent to obtain it without extraneous aid. Advanced knowledge in science is not in general important to those engaged in the ordinary business of life, but on the other hand, a total ignorance of it, on the part of the vast number of persons engaged in constructive and manufacturing processes, is a hindrance to individual progress and a loss to the nation. Every branch of skilled industry would benefit if those employed in it were instructed in the scientific principles involved in the business, and the burden of labour would be lightened if accompanied by a more intelligent interest in the work performed. If boys acquired at school a rudimentary acquaintance with science, they would be in a position when they went to business to follow up, in leisure hours, their previous instruction, and many a fine intellect, which would otherwise be wasted would be brought into useful play. As it is, the absence of a knowledge of first principles, acquired under school discipline, renders self-instruction so difficult and laborious that few are found to attempt it. Moreover, the time which can be devoted to the acquisition of science after a boy goes to business is necessarily very limited, and his studies cannot be permitted to encroach upon the work which he is practising with a view to a livelihood. In school days there is nothing to conflict with learning, and in my opinion the great requirement for the diffusion of useful scientific knowledge is adequate means of instruction in schools. The facilities which are afforded in the shape of public libraries and evening classes are already very great, and bear excellent fruits, but nothing would so much expand the good effects of those facilities as preparatory instruction in science at an earlier age. The business of life is too exigent, in the case of the operative and lower middle classes, to permit of any delay in its commencement beyond the usual time of leaving school, or to render admissible anything in the nature of college instruction concurrently with the learning of a trade. Books and evening classes are the only sources of information open to an ordinary apprentice, and the extent to which he can avail himself of their advantages will chiefly depend upon his being prepared for self improvement by preliminary instruction in school-days. I therefore think the Companies would do well to give at all events their primary attention to the fostering of scientific instruction at school.

There is nothing that has made more rapid progress of late years than the art of teaching. No one can visit a well conducted modern school (and most are well conducted) without being forcibly struck with the extremely efficient manner in which instruction is conveyed to the pupils and the rapidity with which they are brought forward, but it is no part of the system of education usually followed at elementary schools to give any instruction in science, and as a rule, school masters admirably qualified as they generally are for imparting what they teach, are utterly incompetent to teach science. To do this effectually in a school would require a man to be at once a schoolmaster, a lecturer and an experimentalist, and our present schoolmasters have had no means or opportunities of acquiring such combined qualifications. Apparatus, models and specimens are also indispensible for scientific instruction, and the cost of such things would be a great obstacle to their use in popular schools. To provide competent teachers in science and to supply them with the necessary apparatus and other auxiliaries for teaching, is the first thing to be done for the introduction of technical instruction in schools, and as a primary measure, I recommend the Livery Companies to establish a Training College in London for teachers of science.

As the time which can be devoted to science at school must be short, the chief object of a Training College should be to inculcate the best methods of imparting scientific knowledge, so that the brief time that can be spared may be used to the best possible adavantage. The question of how to deal with the teachers after leaving the College, so as to render their services fully available for the ultimate purpose in view, does not seem to me to press for immediate solution. Even if the Companies stopped short at the establishment of a Training College, they would have made a most valuable contribution to the cause of Technical Education, for it may fairly be presented that almost every young man destined for the profession of a schoolmaster would avail himself of a cheap or gratuitous education in science such as would afford superior qualifications for his intended vocation. The growing appreciation of Technical Education would, in all probability, create a great demand for such schoolmasters but if it failed to do so at first, the Livery Companies might lead the way by bearing the expense of giving to some of the most important of the popular schools in London, the gratuitous services of teachers from their College.

The more affluent classes would also participate in the advantage of a supply of trained teachers of science, many of whom would, doubtless, commence schools of their own for the children of those who could afford to pay with sufficient liberality, and who would be able to prolong the period devoted to their children's education beyond the early age at which the children of poor persons must be taken from school.

It would, however, be open to the founders of the College to carry their good intentions beyond the point of merely training teachers. They might, in concert with the School Boards and principal voluntary schools of the Metropolis and chief towns of the kingdom, establish elementary schools in science, at which selected boys from the ordinary schools should attend at certain periods, so arranged as to give to all the schools a share of the benefit. The cost of providing the necessary buildings might be undertaken by the Companies, leaving the expense of carrying on the schools either wholly or partially to the local authorities. Other modes of procedure might be devised, but these might be left to future consideration, as nothing can be done until competent instructors, trained in improved methods of teaching science are forthcoming.

The branches of science which possess the greatest amount of importance are :-

1st Mathematics, as applied to Mechanics and practical science.

2nd Chemistry and the allied sciences of Heat, Electricity and Magnetism.

3rd Geology.

To these should be added Mechanical and Freehand Drawing, which is important, both as a means of cultivating the use of the hand, and of giving expression to ideas which cannot be conveyed by language alone.

A correct taste for decoration, both in form and colour, should also be cultivated as bearing upon the many varieties of manufacturing industry, but this subject is scarcely fitted for school education. Nevertheless, it should not be excluded from a Technical College for training teachers, as there would be ample room for schools of design, available both for youth and persons of mature age, in all parts of the kingdom.

If adequate funds be available there is a wide field of instruction, beyond the limits I have indicated, which might ultimately be brought into play, but there is danger in attempting too much at first. Mistakes may be expected to be made at the outset, and unforeseen obstacles may arise, and these will be more easily corrected and overcome while the undertaking is confined to moderate limits. For example, it would be extremely difficult in appointing, all at once, a large staff of professors and officers, to get in all cases, or even in most cases, the right men in the right places, and persons who have given up other employment for the sake of taking new appointments are not easily got quit of in case of their failing to give satisfaction. For similar reasons, I think the building to be erected as a Training College should not be of very large proportions in the first instance, but should be designed with a view to that great extension which I confidently believe would, at no distant day, be needed if the Livery Company should decide to follow out so good a work to the extent of the public requirements.

I do not think it would be worth while to attempt the instruction of youth in the manual operations of trades. No school can be so good for this purpose as the actual workshop or factory, and the only thing needed is theoretical instruction. But I think it would be a great encouragement to the cause of scientific education amongst the mass of the people, if the Livery Companies were to devote an annual sum to apprenticing lads of scientific promise in the best manufacturing establishments, and contributing to their maintenance during the term of their apprenticeship.

As to the expediency of establishing a technical library, museum, and laboratories, it would be easy to spend a very large sum upon such things without any adequate advantage. There are already so many accessible libraries and museums that there is little need for more, and I think that the College library and museum should be confined to strictly necessary books and specimens. Sufficient laboratories would, of course, be required for the use of the College, but I see no necessity for a larger provision under that head than would be required for the purpose of tuition.

If the Livery Companies should be disposed to extend their aid to scientific education beyond the limit of school life, there is ample room for so doing in providing teachers and apparatus for evening classes. The Science and Art Department has done an immense amount of good by its encouragement of evening instruction, and by paying teachers in proportion to the results of examination. I can speak with great confidence upon this point from my knowledge of the successful working of the evening classes in connection with the Elswick Works, and I scarcely think the Livery Companies could do better, if they go beyond school instruction, than follow in the track of the Government. They should, however, guard against the training of pupils for distinction at examinations rather than for the acquisition of useful knowledge and its application to practical purposes. Training for examination is always liable to degenerate into mere 'cram' which too often leads the successful pupil to attach a higher value to the acquisition of knowledge than to its practical application. Thoroughness of elementary instruction is of far more importance than more ambitious teaching, and the danger of creating tastes and habits which may divert the mind from the business of life, instead of aiding its pursuit, should be constantly kept in view.

It is impossible to estimate what sum of money would be required to carry into effect the measures I have suggested. The question of outlay turns more upon the amount available for the purpose than upon that which is needed, because the scale of operation can be adapted to the sum devoted to the undertaking. Almost any amount might be advantageously utilised in diffusing Technical Education, but whatever sum the Companies may set apart for the purpose, I repeat my doubt of the expediency of rushing into a very heavy expenditure before some experience is gained of the working of the measures to be adopted. A progressive expenditure, starting with a liberal though not excessive appropriation, will, in my opinion, best fulfil the intention of the Livery Companies and, in the end, do more good to the community than a precipitate outlay of the whole available sum.

Although I have treated of education in science and art from a purely economic point of view, I must not be deemed insensible to its claims as a means of intellectual culture; but arguments in its favour based on utility are quite sufficiently strong to render superfluous those which rest upon sentiment".

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