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Almond, J.K.: 'Factors influencing education in metallurgy in England and Wales 1851 - 1950', M.Ed. thesis, University of Durham, submitted 1982-83.

Abstract:

The scale and range of metal industry both expanded greatly during the period 1851 - 1950, and there also occurred a large increase in the understanding of metals and alloys, materials vital for engineering. On these grounds it might be expected that the discipline of 'metallurgy' would occupy a key position in formal teaching programmes, but the reality was different: metallurgy classes did show growth, but it was only small by comparison with that in many other subjects.

To account for the relatively-poor showing of metallurgy, the effects of a number of agencies have been examined. It is considered that industry's influence on instruction was largely negative; job opportunities for those who possessed formal training were few, poorly paid, squalidly situated, and lacking in prospects. By contrast, among individuals a few, including several teachers, made outstanding positive contributions, either by persuading boards of directors to give substantial funds, or as ambassadors for metallurgy at meetings of learned societies and in Government committees.

State encouragement was manifested in several ways: there was a background effect upon general schooling; more importantly, trading factors led to the provision of increased technical instruction; and thirdly, military aims prompted financial investment in technological and scientific tuition.

Metallurgical instruction received help from various societies, e.g. the Society of Arts, the London livery companies, the Iron and Steel Institute, and the Institution of Mechanical Engineers. These last two bodies, with others, published useful papers which furthered knowledge. In 1945 a professional body, the Institution of Metallurgists, came into being and at the same time a national certificate scheme in metallurgy was started. These developments marked real progress. It is suggested that, particularly in earlier years, growth was impeded by metallurgy's academic and industrial subordination to chemistry and to engineering, which resulted in the lack of any clearly-perceived distinctive identity.

Factors Influencing Education in Metallurgy
in England and Wales 1851 - 1950

by

John Kenneth Almond,
ARSM, Ph.D.(Eng.), MIMM, Cert.Edn.(Tech.)

Thesis submitted for the degree of M.Ed. in the
Faculty of Education, University of Durham,

December 1982



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Brief References

The following abbreviations have been used in the text where particular published works are referred to on numerous occasions within one chapter.

<u>Brief reference</u>	<u>Full title of work</u>
Argles (1964)	Argles, Michael, <u>South Kensington to Robbins an account of English technical and scientific education since 1851</u> , (Longmans, 1964).
Boyd (1975)	Boyd, Derek, <u>The Royal Engineers</u> , (Leo Cooper, 1975).
Carpenter (1924)	Carpenter, H.C.H., 'Metallurgical education of university rank in Great Britain', in <u>Proc.(1st) Empire Mining Metallurgical Congress, part 5 ...</u> , (Instn.Mining Metallurgy, 1925), 43-90.
Education Survey (1927)	Board of Education, <u>Survey of technical and further education in England and Wales</u> , (HMSO, 1927).
Macleod (1977)	MacLeod, Roy M., 'Education: scientific and technical', in Sutherland, G. and others (eds.), <u>Education government and society in nineteenth-century Britain ...</u> , (Dublin: Irish Univ. Press, 1977).
Maclure (1973)	Maclure, J.Stuart, <u>Education documents England and Wales 1816 to the present day</u> , (Methuen, 1973).
Survey (1950)	Anon., 'A survey of the facilities for metallurgical education in England, Scotland, and Wales', <u>Bull.Instn. Metallurgists</u> , vol.2, no.5 (Mar.1950), 14-25.

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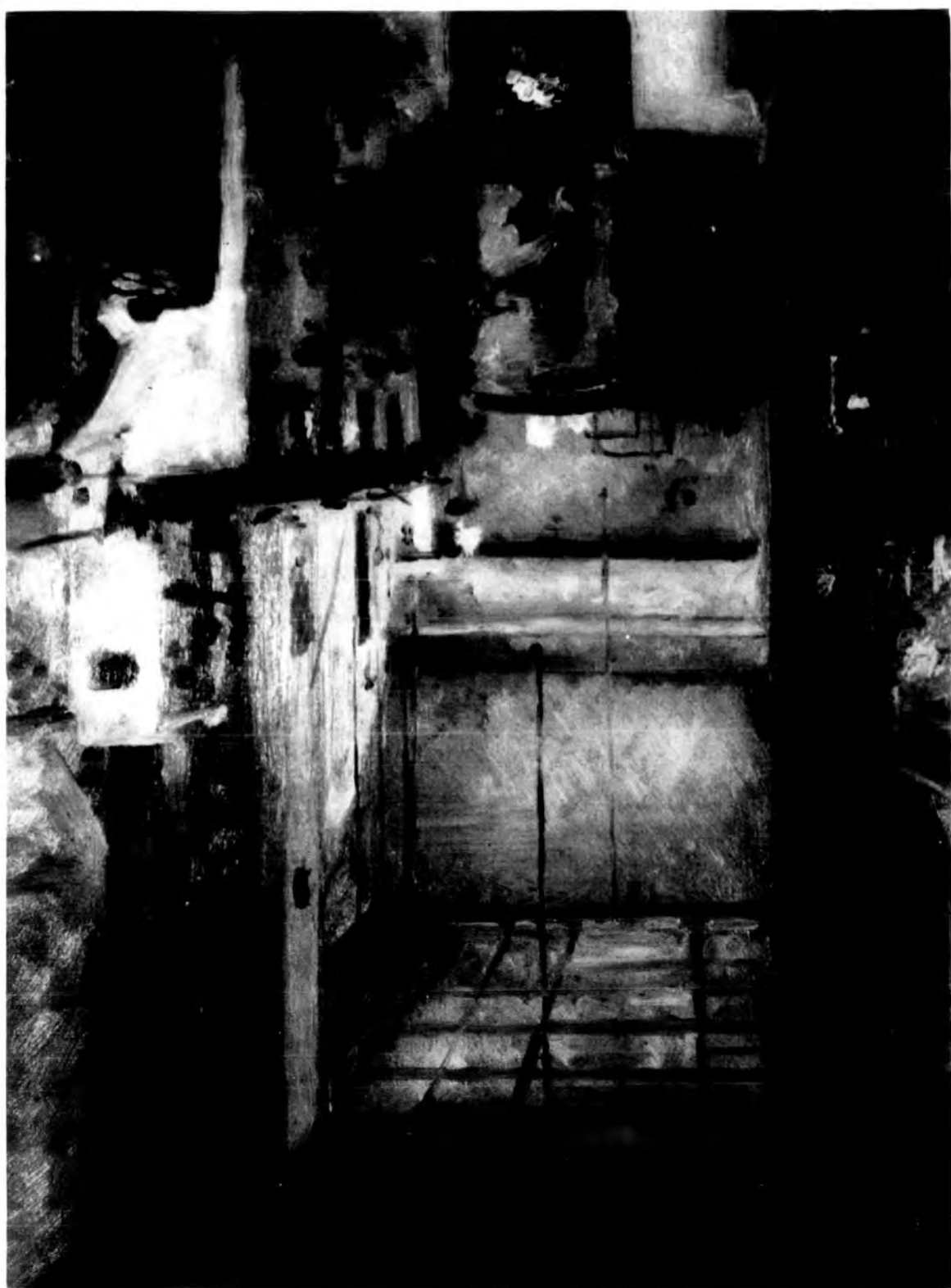
Extensive library facilities have been made freely available by three organisations: the North of England Institute of Mining and Mechanical Engineers in Newcastle-upon-Tyne, Secretary Mr.R.Williams and Librarian Miss Margaret Norwell; the Cleveland Scientific Institution in Middlesbrough, Secretary Mrs.B.C.Bond; and the Teesside Polytechnic in Middlesbrough, especially the inter-library loan section headed by Mrs.J.Beck.

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The writer's wife, Honor Brigid Almond, has more than once expressed the view that the period involved in the preparation of this thesis seemed like a hundred years.

Declaration

No part of the material contained in this thesis has previously been submitted for a degree in any university.



CHAPTER 1

THE METAL INDUSTRY

In the century 1851 - 1950, the metal industry was on a large, and increasing, scale. In terms of bulk, iron with its derivative steel was predominant both on a world-wide basis and in Britain: indeed, these allied materials can be said to be the essentials upon which civilisation throughout the period was founded. Appropriately, the Crystal Palace in Hyde Park, symbol of the Great Exhibition of 1851, itself depended upon a framework of cast iron.

In the quinquennium 1851-55, world pig-iron production amounted to some five million tonnes a year, of which Britain contributed very nearly one half. During the subsequent hundred years, British output of iron and bulk steel increased six-fold to reach fifteen million tonnes in 1950 but this increase, though in itself important and impressive, was dwarfed by the corresponding twenty-eight-fold increase in world production. As a result, instead of accounting for fifty per cent. of output, British steel producers became responsible for less than ten per cent. of the total. The variation of iron-and-steel production with time is shown graphically in Figure 1.1; the values up to 1920 relate to pig iron which until then was produced in greater quantities than steel, but after 1920 bulk steel became the larger commodity, and consequently in the later years figures for steel rather than iron are presented.

In a general way, the pattern of iron-and-steel production during the period 1851 - 1950 is mirrored by that for other major metals, Figure 1.2. British output of these combined non-ferrous metals was 98 000 tonnes a year in 1851-55, one-third of the world total of 286 000 tonnes. By 1946-50, output in Britain had increased about five times to more than 450 000 tonnes, but meanwhile the world total had multiplied almost



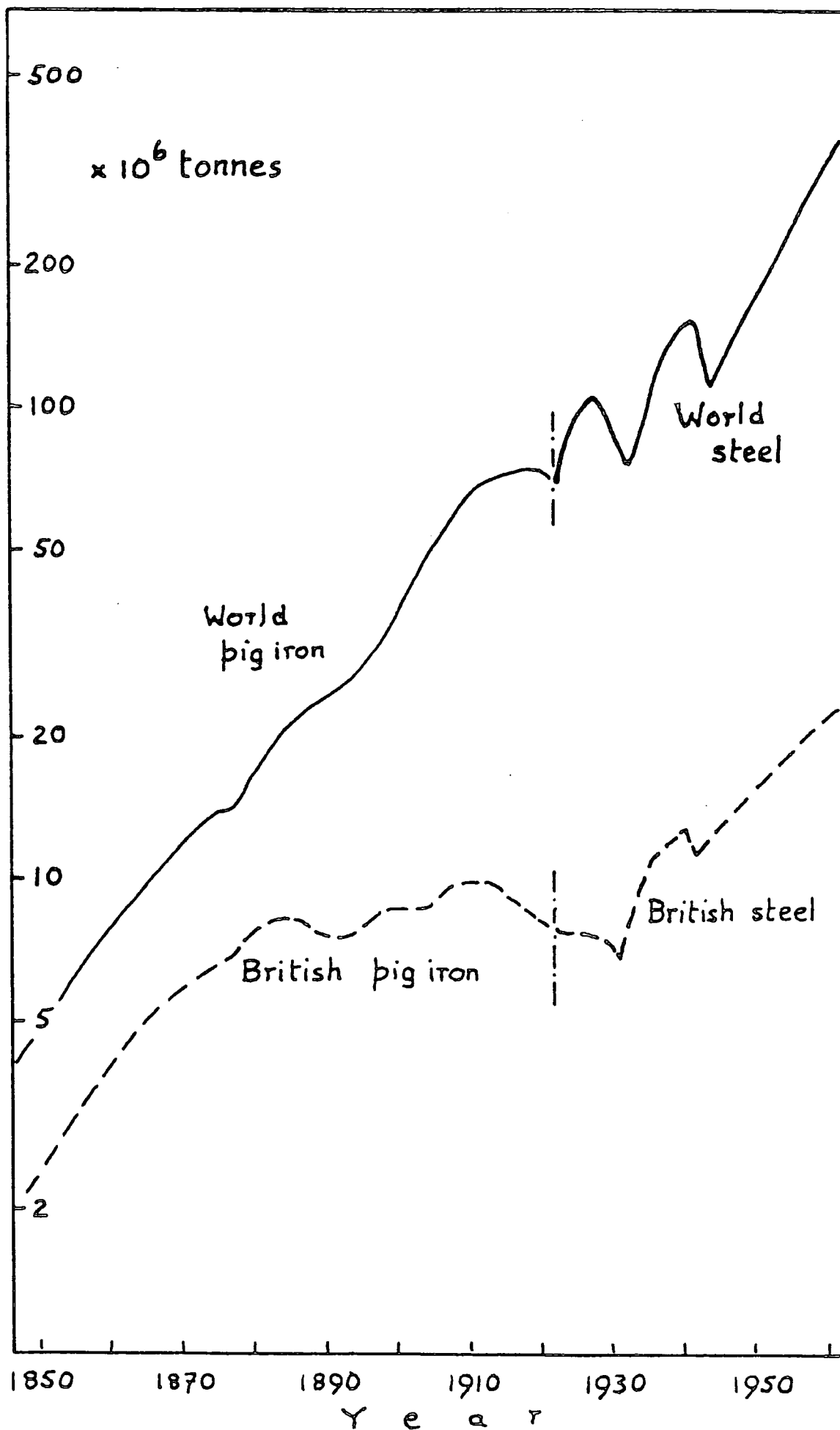


Figure 1.1. Variation of iron and steel output with time (based on five-year averages).

thirty-fold to 8.5 million tonnes. Consequently, as with the ferrous metals, Britain's contribution to world non-ferrous production dropped from a substantial fraction in the 1850s to a diminished proportion in later decades. Indeed, British output of non-ferrous metals amounted to less than ten per cent. of world production by the opening years of the twentieth century, while the country's iron and steel did not fall below ten per cent. until after 1925. The five-fold increase in British non-ferrous metals during the period 1851 - 1950 was uneven in its development: the first two-and-a-half-fold increase took 80 years to accomplish whereas the second similar expansion occurred within the remaining twenty years between the 1930s and the early 1950s. The graph, Figure 1.2, reveals that for a period of nearly thirty years, from 1895 until after 1920, there was an absolute decline in British non-ferrous metal production.

One further relevant contrast between metal production in Britain and that for the world as a whole concerns the relationship between iron and steel on the one hand and the non-ferrous metals on the other: in Britain the ratio of output, in tonnage terms, has varied from 30/1 to more than 60/1, but world-wide the corresponding ratio has been confined within the band 15.6/1 - 22/1. In other words, world-wide, the ratio of iron and steel produced to other metals has remained reasonably uniform throughout the hundred-year period while in Britain not only has the ratio fluctuated widely but iron and steel have had an uncommon dominance.

So far, metals have been discussed in terms of quantities produced. If value is considered rather than quantity, more uncertainties arise in developing estimates, not least because of the difficulty in establishing a uniform standard. Such treatment lies outside the scope of the present work; suffice it that the price trends for the chief non-ferrous metals are shown graphically in Figure 1.3, while in Table 1.1 are given estimates for the values of British non-ferrous production in various years.

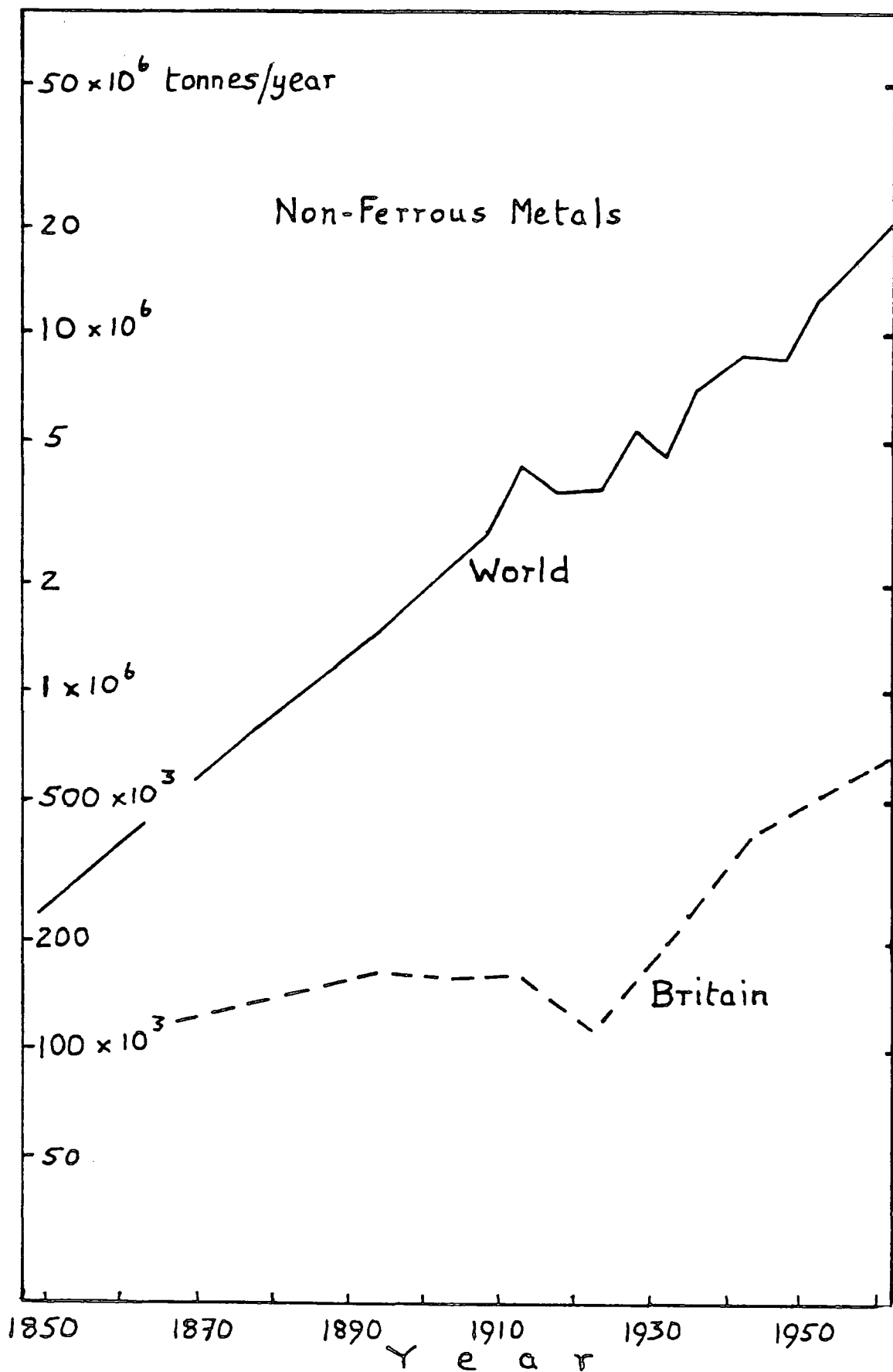


Figure 1.2. Non-ferrous metal production, 1851 - 1960
(five-year averages).
Compiled from data given in SCHMITZ, Christopher J.,
World non-ferrous metal production and prices,
1700-1976, (London: Frank Cass, 1979), pp.430.

Table 1.1. Estimated value of British non-ferrous metal production in selected five-year periods

M e t a l	<u>Average Value (approximate), £ x 10⁶/year</u>				
	(1851-55)	(1901-05)	(1931-35)	(1936-40)	(1946-50)
aluminium	-	-	-	-	9.8
copper	1.7	4.5	3.6	7.5 (estimated)	24.0
lead	1.35	0.4	0.25	0.4	3.4
magnesium	-	-	-	0.9 (estimated)	0.6 (estimated)
tin	0.65	1.4	5.25	8.4	15.4
zinc	0.1	0.9	0.6	1.0	5.5
total value:	3.8	7.2	10.7	20.2	58.7

Derived from data given by SCHMITZ, Christopher J.,
World non-ferrous metal production and prices, 1700-1976.
(London: Frank Cass, 1979), pp. 430.

The figures clearly show a fifteen-fold increase in nominal values over the century 1851 - 1950, accompanying the five-fold increase in quantities produced. There was a doubling of values in the first half century 1851 - 1900, followed by a further doubling by around 1935, while in the subsequent fifteen years values almost quadrupled, i.e. from £15 million to £58.7 million. Coupled with the substantial increase in quantities produced during the same period, this points to considerable enlargement in British metals' activity in the years 1935 - 1950. By comparison with many non-ferrous metals iron and steel are low-value commodities; hence it follows that, judged by financial value rather than quantity, during the century 1851 - 1950 the disparity between British iron-and-steel production and that of other metals was nearer a ratio of four to one than forty to one; by any measure, however, it was still predominant.

These levels of metal production indicate the extent of industrial interest, but they cannot provide an accurate or complete picture of activity involving metals. This is because metals are rarely used in the

simple forms of ingots or bars which result from the production stages. Particularly in highly-industrialised countries such as Britain, considerable activity is associated with the application of metals to yield useful products, and this was the case throughout the century 1851 - 1950. Some measure of the extent of overall national involvement in metals can be gained from figures relating to the year 1935, Table 1.2.

Table 1.2. British metal industries in 1935

S e c t o r	Number of employees	Value of output, £ x 10 ⁶
copper and brass	27 500	19.7
gold, silver, etc.	2 300	30.7
lead, tin, zinc, aluminium, etc.	27 000	33.1
finished brass trade	34 100	11.3
plate and jewellery trade	24 900	8.8
	115 800	103.6
iron-and-steel industries	331 600	206.3
	447 400	309.9
Hence, proportion of metal-industry employees engaged in ferrous industries: three quarters		
proportion of output value attributable to ferrous industries: two thirds		

HUTTON, R.S., 'The training and employment of metallurgists'. Monthly Jrnl.Inst.Metals, vol.4, pt.12 (1937), 636; quoting figures provided from Government reports by O.W. Roskill.

The figures in Table 1.2 demonstrate the relative preponderance of ferrous industries. They also show that, as far as non-ferrous metals are concerned, the value of the manufactured output, £103.6 million, amounted to seven times the value of raw metals produced within the country. Incidentally, the original object of the statistics for 1935 quoted in Table 1.2 was to indicate the relationship in Britain between the metal and chemical industries, the corresponding figures given for chemicals being a manpower involvement of 88 000 and an output value of £80.2 million,

or one-fifth and one-quarter respectively of their metallic counterparts.

A further indication of the growing importance of metals during at least a portion of the period under review is given by the proportionate increase in consumption of some non-ferrous metals relative to the world's population, Table 1.3.

Table 1.3. Consumption of metals per head of world's population in 1900 and 1936

Year	<u>M e t a l c o n s u m e d, grams/person</u>				
	aluminium	copper	lead	tin	zinc
1900	4.9	354.8	587.6	55.0	320.2
1936	196.8	853.0	759.0	83.0	725.0
proportionate increase 1936/1900	40/1	2.4/1	1.3/1	1.5/1	2.3/1

ANON., 'Development of metal consumption; increased demand per head of population, Metallgesellschaft's survey'. The Metal Industry, vol. 51 (8 Oct. 1937), 362.

As already discussed in connexion with the trend in production for combined non-ferrous metals, Figure 2, overall world production rose by some thirty-fold between 1851 and 1950. For a number of individual metals, the growth in world production is presented graphically in Figure 4. Gold production rose by a factor of four, while tin registered an eight-fold increase; by contrast, copper displayed a forty-fold increase. During the hundred-year period, several new metals became industrially important: nickel and aluminium both started off from less than 15 000 tonnes in 1901 but, by 1950, nickel had registered an expansion of more than a hundred-fold while aluminium's growth had been even more spectacular, equivalent to a thousand-fold increase. Magnesium came to prominence after 1930. The metallic element uranium assumed industrial significance, though not for its mechanical properties, in the last decade, i.e. 1941-50. By the late 1940s, the prospects for titanium were being discussed in

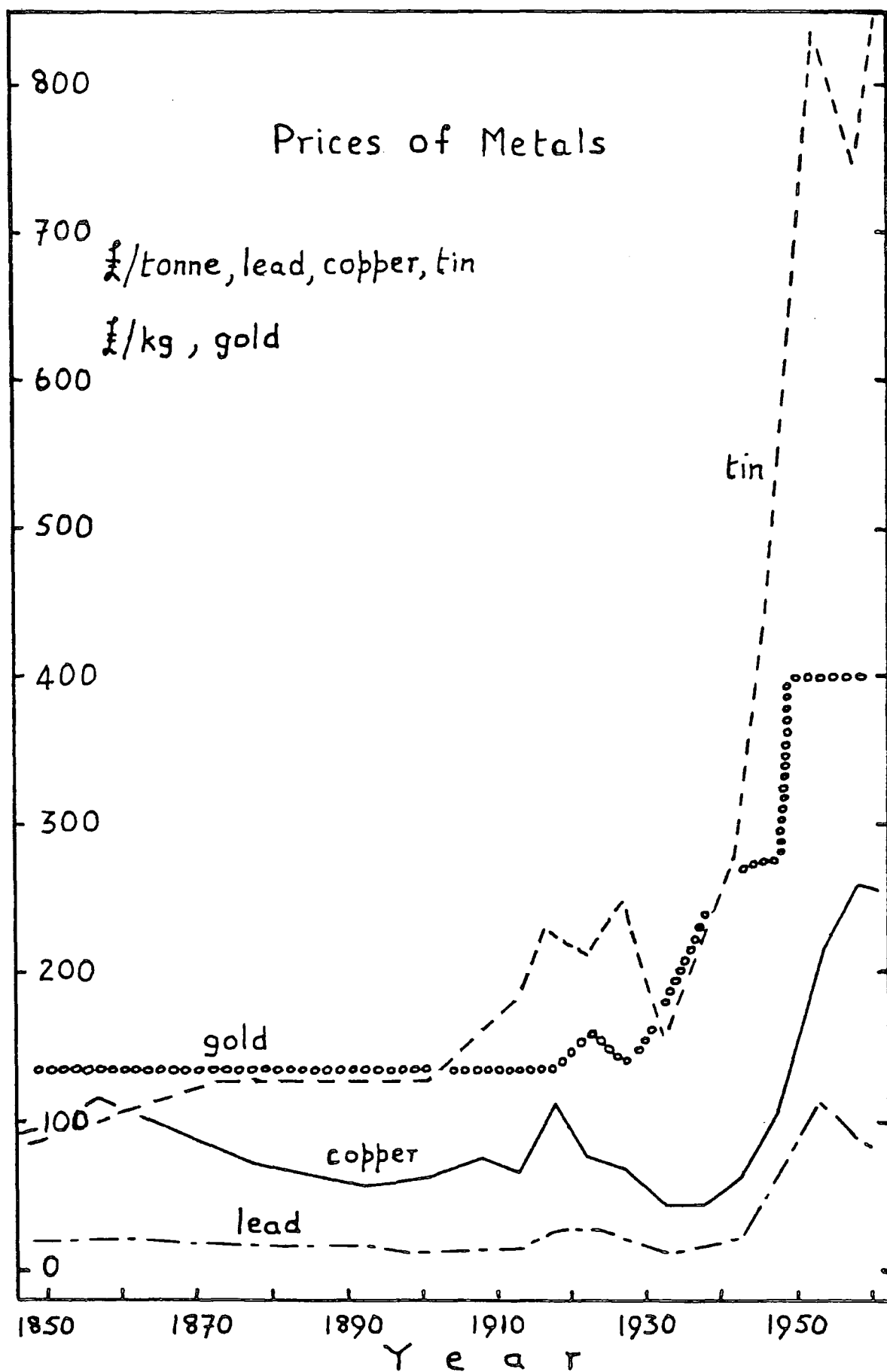


Figure 1.3. Price trends for some important non-ferrous metals (based on five-year averages). Compiled from data given in SCHMITZ, Christopher J., World non-ferrous metal production and prices, 1700-1976. (London: Frank Cass, 1979), pp.430.

glowing terms. British activities in producing and/or refining non-ferrous metals during the 1940s included: zinc and cadmium refining in Swansea and Bristol, tin smelting in Bootle, platinum and silver refining in London, nickel refining in Clydach, lead refining in Gravesend, and the production of primary aluminium and magnesium.⁽¹⁾

The impressively large demands for metals during the century 1851 - 1950 were met by the exploitation of mineral deposits situated in many different areas of the world, a high proportion of them newly worked after 1851. Only in the case of gold and other precious metals were substantial proportions of the elements found already present in metallic form: in all other instances treatment, sometimes elaborate and costly, was necessary to convert the mined ore into saleable metal. Gradually, as metal consumption increased in the industrialised countries, recirculation of scrap and its treatment to yield 'secondary' material grew in importance as a source; for example, during the 1940s British production of secondary aluminium exceeded that of primary metal.

Demands for gold were met not only from new mining fields specifically for the metal but also from the refining of other metals, notably copper. The 'rush' for Californian gold had started in the late 1840s, and by 1851 that source was contributing three-quarters of the world total. However, almost immediately gold was found in Australia which, in its turn, soon accounted for one-half of the total. New Zealand production assumed significant proportions in the 1860s. By this time too, Canadian placer deposits were yielding the metal, while in the USA vein deposits in Nevada were responding to the technological skill required to treat them successfully. During the 1880s, the Witwatersrand deposits of the Transvaal region of South Africa came into production. By the opening of the twentieth century, British empire producers vied in importance with those of USA and Russia, and the prime gold district in the USA was at Cripple Creek, Colorado, where the ore occurred as refractory telluride which for its extraction required heat treatment, that is, 'roasting'.

(1) CHASTON, J.C., 'Non-ferrous metallurgy a century of British progress'. The Metal Ind., vol. 71 (4 July 1947), 8.

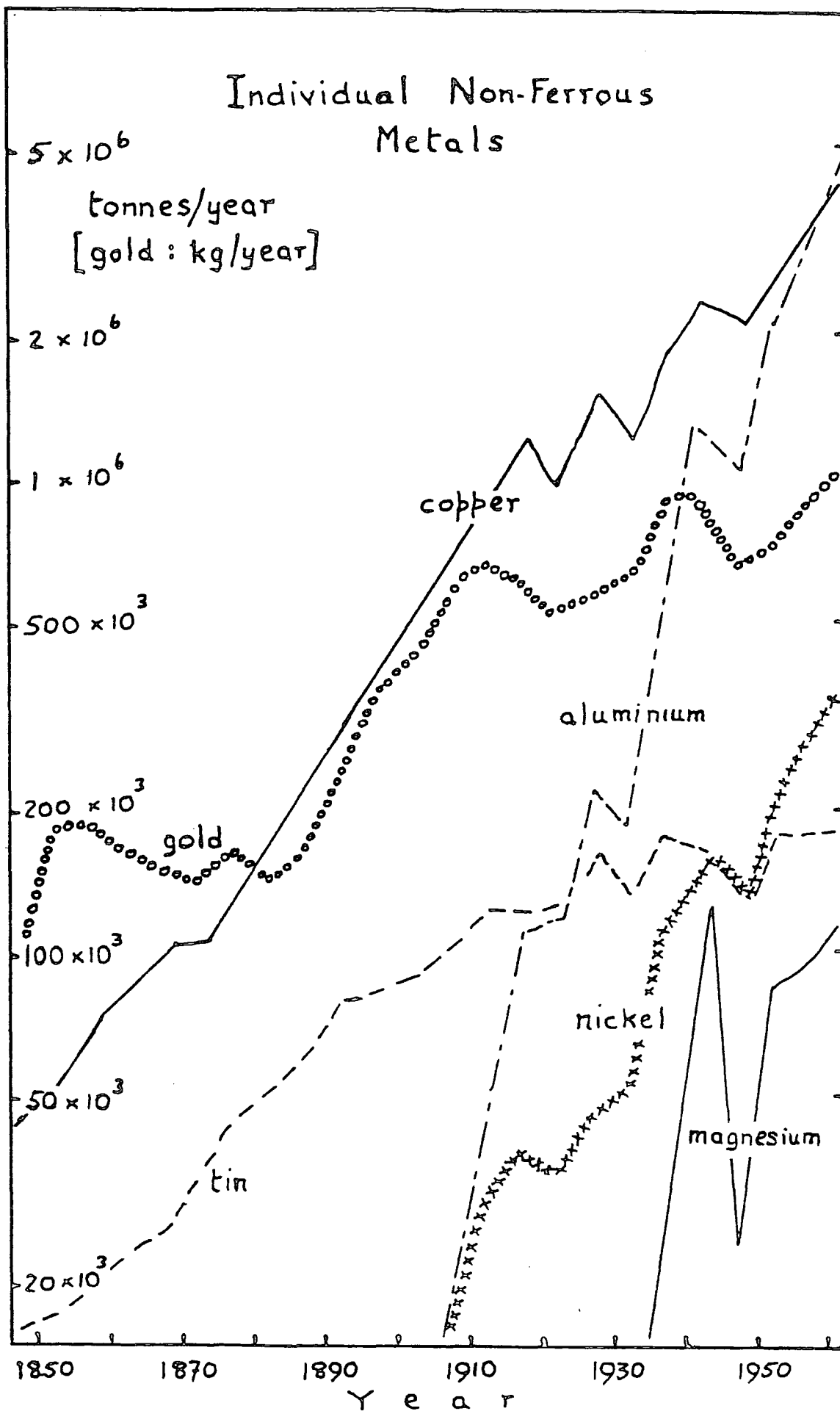


Figure 1.4. Growth in world production of individual non-ferrous metals, 1850 - 1960 (based on five-year averages).

Placers in the Yukon and Alaska sprang into prominence in the late 1890s, as did deposits in Western Australia; empire outputs were augmented by metal from the Kolar field in South India. In the forty years between 1851 and 1890, in those cases where the gold ores demanded chemical treatment this was commonly met by 'amalgamation' of the crushed rock with mercury, but from 1890 a new treatment method, involving dilute cyanide solution, became available. In the subsequent 55 years, the 'cyanide process' was taken up widely, enabling gold to be extracted profitably from rock otherwise unworkable. The handling of large volumes of aqueous solutions and ore pulps, and the addition of reagents in suitable proportions, called for knowledge of both chemistry and engineering.

As far as copper was concerned, 1851 saw a fair proportion of world metal output concentrated in the Swansea district, where a laborious treatment technique had been established in the previous century, requiring consumption of around twenty tonnes of coal for every tonne of copper made. However, in the second half of the nineteenth century, fresh copper smelters were set up nearer to the sources of contemporary ore, for example in the USA, Chile and Australasia. During the twentieth century, Canadian and central African copper smelters contributed substantially. As the scale of working, and the size of individual items of equipment, increased, so there came a greater need for engineering and managerial skills. One innovation in technique introduced during the 1880s and 1890s was substitution of 'converting' for part of the established processing sequence, using a modified Bessemer vessel; although economically successful, this brought added engineering problems to the smelter. Another aspect of copper smelting which received increasing attention was the containment of the noxious sulphurous gases liberated during treatment. There also came developments in alternative methods for extracting the metal from ores: instead of high-temperature smelting, in certain instances it proved feasible to dissolve the copper from its containing rock by dilute aqueous acid or alkali. Such leaching techniques, although involving skills similar to those required by the cyanide process for gold, did not come to occupy a corresponding key position in the extraction of copper. However, one significant application of leaching in Britain was in the 'wet treatment of cupreous pyrites' which was begun in the 1860s and persisted on Tyneside

until the 1930s; by its means copper, together with some silver, were extracted from very large quantities of Spanish pyrites mined primarily for their sulphur content. Wet processing also entered into copper refining operations, for some of the metal resulting from smelting was subjected to electrolysis in copper-sulphate solution to remove, among other elements, contained gold and silver.

As with copper, so with lead, in 1851 a considerable proportion of world output came from British smelters but in subsequent years new producers started work elsewhere. Among other places, the new ores were treated in the USA, Canada, Mexico and Australia. Like copper ores, treatment generated large quantities of sulphurous gases; in addition there was toxicity to contend with. Lead refining, to purify the metal and yield economic byproducts, saw several developments during the period under review: even before 1860 the versatile Alexander Parkes of Birmingham introduced a new way of separating silver from the base metal; during the twentieth century methods were devised to isolate bismuth, to effect the separation of antimony more economically and, in Australia, to achieve continuous working in the refinery.

The zinc, which was so commonly found in nature allied with the lead as sulphide, was a more difficult metal to extract, first production in the western world having occurred as lately as the first half of the eighteenth century. Even in 1840, world output of zinc metal did not exceed 20 000 tonnes; nearly all of this came from Belgium and Germany/Poland, which continued as major world smelters until after 1950. By the early part of the present century, however, the USA had become a substantial producer, and in later decades other notable contributors included Canada and Australasia. Britain maintained sizeable facilities for smelting zinc and for producing refined lead. The difficulties inherent in obtaining zinc from its ores by smelting prompted the development of alternative processes: research carried out in Britain in the 1880s and 1890s had no commercial success but, on the other hand, a German process was operated for more than a decade by Brunner Mond in Cheshire soon after 1900, and from about 1915 a leach-electrolysis method came into use in the USA. This treatment scheme was subsequently adopted by other zinc producers: it involved roasting the high-grade zinc sulphide to oxide, leaching

with dilute aqueous sulphuric acid, purification to yield zinc-sulphate solution, and electrolysis to deposit solid zinc metal. Close attention to chemical control at all stages was essential for success, and a large number of problems had to be overcome to achieve acceptable extraction efficiency. Meanwhile, the difficulties associated with high-temperature processing of zinc ores continued to receive attention: in Britain work done during the 1940s was to lead, in the following decade, to industrial success with a 'zinc-lead blast furnace', also known as the Imperial Smelting Process. Another technical difficulty in the treatment of mixed ores of zinc with lead or copper, that of separating the zinc-sulphide mineral from the lead or copper sulphides, was solved soon after 1901 by international effort involving workers in Britain, the USA and Australia; by careful dosing of the mineral pulp with suitable chemical reagents they achieved 'selective froth flotation', which in many mineral-processing plants proved a boon for isolating minerals of zinc and other metals.

Aluminium was a 'precious metal' in the 1850s, and regarded as an exotic curiosity. In France, Deville won the support of Louis Napoleon III in his attempts to produce the metal commercially, and in London Dr. John Percy of the Royal School of Mines was associated with early specimens produced in the capital. It is said that for a time a sample of the metal was exhibited in the front window of the Royal Polytechnic Institution in London, at which Henry Pepper delivered popular scientific lectures. During the 1860s, small quantities of British aluminium were made near Newcastle-upon-Tyne, using Deville's technique; again, in the early 1880s, commercial production was attempted, this time using as reagent metallic sodium prepared by Henry Castner's new method. However, by the later 1880s there appeared an alternative means of obtaining the metal, based on high-temperature electrolysis of a fused salt of aluminium. This electrolytic method formed the basis of all commercial production of primary aluminium throughout the subsequent 70 years. The aluminium fed to it had to be in the form of pure oxide, and to make this entailed leaching the ore with hot caustic-soda solution, followed by careful precipitation of the wanted material, filtration, and kilning to drive off water. It soon became recognised that extraction of the metal could be done in two geographically-separated stages, the first to yield the pure aluminium oxide

and the second to convert this intermediate substance to metal. The former treatment was most conveniently carried out near to mineral deposits rich in aluminium, while the latter required large quantities of electrical energy, Norway and Switzerland being two European countries in which it was practised. In Britain, aluminium production based upon Scottish hydro-electric power was started in 1896; by the 1930s most industrialised nations were producing the metal, with the USA and Germany leading the field.

In terms of quantities produced, iron and steel far outstripped all other metals put together at all stages of the period 1851 - 1950. The technique of making iron that was suitable for castings, using coal as fuel, had been worked out in Britain during the eighteenth century, and a measure of fuel economy was already being obtained in 1851 by heating the air blast to the furnace. Moreover, the subsequent treatment needed to change the brittle, but low-melting, material from the blast furnace into metal with good mechanical properties and suitable for engineering purposes, had been established prior to 1851: it involved 'puddling' the crude metal in a coal-fired furnace and then kneading it mechanically by hammer and rolls, to yield 'wrought iron'. As far as ironmaking itself was concerned, the increasing demand in the years 1851 - 1950 was met by a combination of modifications, but no fundamental changes, to the blast-furnace process. Bigger furnaces with greater airblasts yielded larger quantities of hot metal. To feed these furnaces mechanical charging devices were introduced, initially in the USA. In some cases the ore was heat-treated, or calcined, before charging; later, in the closing years of the period under review, at a number of plants the material was subjected to 'sintering' before being charged. To provide higher-grade feed, some ores were brought from considerable distances: Spanish ores were first imported into Tees-side in the 1870s, and Scandinavian materials followed from 1900. At a number of mining sites dressing methods were introduced to up-grade the ore, for instance, magnetic separators were installed in Scandinavia around 1901. The coal needed by the iron blast furnaces had to be coked before charging; it became the practice to recover byproducts such as coal-tar from the coking process. To maximise the income from such byproducts skilled men

were sometimes considered worth hiring.

By contrast with the basically-unaltered nature of world ironmaking, the subsequent treatment of the hot-metal product underwent radical changes during the period under review. As it happens, the transformation was initiated within a few years of 1851 and the Great Exhibition. Henry Bessemer announced to the British Association's meeting in Cheltenham in 1856 the details of his scheme for blowing the impurities out of liquid blast-furnace iron by means of an air jet. While there was nothing new in this proposal, what was revolutionary was the idea that, during the procedure, sufficient heat could be generated to yield at the end of the blow, in place of the pasty mass of metal and slag which always resulted with the puddling furnace, molten metal. Despite difficulties in translating the idea into reliable practice, Bessemer's method was adopted from 1860 and gave to the world a new material: 'bulk steel'. For convenient execution of the technique a new kind of vessel was used: a cylindrical, tiltable, iron pot. Soon 'converters' able to handle five tonnes of molten metal became accepted items of equipment, and later their sizes increased to give capacities, by the 1940s, of 50 or even 60 tonnes.

Bessemer's revolutionary steel-making technique, however, soon had a rival, developed using the high temperatures the Siemens brothers found it possible to generate within a standard reverberatory furnace. By use of these new high temperatures liquid steel could be produced on the open hearth of the furnace, resulting in the 'open hearth process' which entered commercial work around 1867. During the first half of the twentieth century, open-hearth furnaces were responsible for producing the major bulk of world steel. Large open-hearth furnaces in the 1940s were able to supply up to 100 tonnes of liquid steel at a time. By that date, they were supplemented by electric-arc furnaces which proved particularly useful both for re-processing steel scrap and for preparing alloy steels containing deliberate proportions of elements besides iron and carbon.

As originally worked, neither Bessemer's converter nor Siemens' open-hearth furnace was able to deal with any phosphorus which might be present in the metal; because of the deleterious effect of phosphorus on the mechanical properties of the resultant steel this was a serious

shortcoming, and during the 1870s it severely restricted the deposits of iron minerals which might be used. Considerable investigational work was done in several countries in attempts to find a solution to the phosphorus problem: to Sidney Thomas and Percy Gilchrist, the latter an Associate of the Royal School of Mines in London (ARSM), go major credit for providing a practical answer. From 1880, their conditions of 'basic' steelmaking were rapidly applied in European industrial countries. Throughout the following 70 years, minor modifications were constantly made to steel-making practice, for instance, in the kind of fuel used to fire open-hearth furnaces, in order to meet in the best way the prevailing economic conditions.

The design and maintenance of steel-making equipment required considerable engineering skill, as indeed did that of a large blast-furnace plant in the 1930s when equipped with mechanical charging appliances, hot-blast stoves and gas-cleaning facilities. Moreover, control of the steel-making process called for some kind of chemical analysis, although in fact many plants were run for years without adequate technological knowledge.

A development which began to bear fruit in the 1890s was the production of steel with improved properties that resulted from the addition of certain elements to the refined iron. One of the first 'alloy steels' to come into widespread use was rich in manganese and its introduction was due to Robert A. Hadfield, son of ^aSheffield steelmaker; another incorporated nickel to yield higher strength. In the first decade of the new century, there followed silicon-containing steels which were applied to components for the electrical industry such as transformer cores, and tungsten-bearing steels which were found to produce better tools for machining other metals and also ^{to} yield armourplate for military purposes. Two further lines of development had profound significance after 1911. One was the extended use of alloying additions to give stronger, tougher materials for structural purposes: shortly before 1930 the 503-metre (1650-foot) arched span of the Sydney Harbour Bridge was constructed in such alloy steel by a British company. The other field of growth occurred with the so-called 'stainless steels', whose resistance to corrosion was first exploited by Harry Brearley of Sheffield c.1913. These various alloy steels required substantial quantities of elements such as chromium, nickel, molybdenum and tungsten, although for steel-making purposes relatively-crude smelting processes sufficed to prepare the additives from their ores.

A new problem, that of solidifying tonnage quantities of liquid metal, was posed by the advent of bulk steel in the 1860s; considerable modification of established techniques by trial and error took place before reliable solid ingots of large size, capable of yielding high proportions of useable material, became the norm. Once the ingots, or solid blocks, of steel had been formed, the task became one of shaping the material into saleable products, such as plates for boilers and ships' hulls, railway and tram rails, structural 'I' beams and channels, thin strip for bending into tinned food containers, round rods of assorted diameters, and tubes. Prior to 1851, effective methods for carrying out these forming processes had been established, but the greatly-increased scale of production after that date, coupled with availability of the new bulk steel, demanded forging hammers, presses, and rolling mills of larger size. In the 1870s leading steel producers, such as the Dowlais Works in South Wales, were processing 1000 tonnes a week of ingots; by the late 1920s the scale of working had multiplied ten-fold, with 'reversing cogging mills, fitted with modern appliances' able to 'cog down 10 000 tons of ... ingots', so that the output of rails from such plant had increased from 600 to 5000 weekly tonnes. Similarly, in producing wire rods, while a weekly outturn of 25 tonnes of 9.5 mm ($\frac{3}{8}$ -inch) diameter rounds was considered fair in 1860, by 1927 'the same size and type of mill' was making 400 tonnes of smaller steel rods in the same time.⁽²⁾ These increases in tonnage, with which were associated widened ranges of available products, were achieved by developments in the machinery used for processing. Larger sizes and power, application of fresh designs, and improved engineering accuracy all contributed to the overall results. In 1850, plates of copper weighing more than a tonne were being rolled,⁽³⁾ but in general during the period under review it was the shaping processes for bulk steel which led the way; then, as need arose, these methods were adopted for other materials, such as copper alloys and aluminium.

Among the extensions made to the range of steel articles was 'seamless'

(2) HALL, J.W., 'The development of the rolling mill with the advent of steel'. Iron Coal Tr.Rev. Diamond Jubilee Issue, (Dec.1927), 160.

(3) CHADWICK, R., 'The working of metals'. Chap.25 in SINGER, C. and others (eds.), A history of technology ..., vol.5. (Oxford: , 1958), 610.
Clarendon Press

tube, whose production depended on a novel German principle first put into practice in Swansea at the Landore Siemens Steel Company in 1887,⁽⁴⁾ and transferred to the USA some ten years later. Another method of forming metal that was successfully extended in scope was 'extrusion'; in this, solid yet plastic material was forced by pressure through a shaped die orifice to yield lengths having the requisite uniform cross section. For making pipes in lead, extrusion had been established before 1851, but the first industrial extrusion of tubes of copper and brass, involving more arduous conditions, took place close to the end of the nineteenth century, with application being made in the 1930s to aluminium and its alloys in increasingly complicated sections.⁽⁵⁾ During the 1930s too, alloy-steel extrusions became feasible.

Another way of forming metallic products came into wider use in the early decades of the present century; this involved creating coherent material by compacting and heat-treating powders of suitable size distribution and composition. An early instance of the use of such treatment was consolidation of platinum sponge, practised by Edward and Percy Matthey in London's Hatton Garden.⁽⁶⁾ The technique attained greater significance when it was applied as part of the complex sequence devised to yield ductile tungsten for better electric-lamp filaments. With its melting temperature of more than 3000°C, tungsten posed particular problems in its treatment, and the sintered powder technique proved especially useful for dealing with such refractory metals. Later, during the 1930s, the application was extended to production of bronze bearings, for example, for internal combustion engines and electric motors.

Following the development of railway networks in many countries, metals, particularly wrought iron and its successor bulk steel, were applied to ship construction, and then to the frames of large buildings. During the first half of the twentieth century, the railway's rival, the mechanical road vehicle, demanded mass-produced metallic components possessing close dimensional tolerance and high dependability. These components

(4) CHADWICK, R., op.cit., 629.

(5) TYLECOTE, R.F., A history of metallurgy. (London: The Metals Society, 1976), 154.

(6) CHASTON, J.C., loc.cit.

included radiators, fuel tanks, carburettors, lamp housings, engines and gearboxes, as well as structural members for the chassis, steering gear and, increasingly, sheet for the bodies. Similarly, the aircraft industry called for reliable, strong yet light, metallic materials. Suitable aluminium alloys were developed around 1910 in Germany and, during the 1920s, at the National Physical Laboratory in Teddington, England. In the 1930s magnesium alloys were also developed, particularly by the Germans. Exhaust valves for aero engines received 'continual research work over the whole of the inter-war period', from which there emerged an advanced design that involved a combination of alloys, accurately shaped and heat-treated to provide the desired properties.⁽⁷⁾ During the final decade before 1951, realisation of a new generation of aircraft engines based on the gas-turbine principle set a fresh problem, that of providing materials which would operate under difficult conditions, at a temperature of about 800°C, that is a good red heat, while subjected to stress.

The new electrical industry which came into being in the second half of the nineteenth century enjoyed close interaction with metals: on the one hand, electrical conduction and generation were wholly dependent upon copper and iron; on the other, application of electrical energy opened fresh avenues for metal industry. By passage of electricity through solutions, 'electroplating' became possible, production of silver-coated cutlery becoming important soon after 1851, while chromium plating of motor-car and domestic fittings became prominent after the turn of the century. Electrolysis of solutions also yielded metallic aluminium in the 1890s at a small fraction of the previous price, £2.20 a kg compared with £132, and later contributed to production of zinc and magnesium. Electrolysis provided a useful tool for purifying metals and for separating valuable byproducts such as gold and the platinum-group elements from copper, the first successful electrolytic copper refinery being erected by G.R. Elkington at Pembrey in South Wales in 1869.

The heating effect of electricity was applied to provide furnaces; these were used for the extraction of metals from their ores, for preparing

(7) ALEXANDER, W.O., 'The utilization of metals'. Chap. 18 in WILLIAMS, T.I. (ed.), A history of technology vol.6 the twentieth century c.1900 to c.1950 part 1, (Oxford: Clarendon Press, 1978), 441-442.

batches of liquid metal in readiness for casting, and for the subsequent heat treatment of solid metals during forming operations. Moreover, and particularly during the last two decades of the period up to 1950, electric heating was adopted for joining pieces of metal by fusion welding, resulting in the large-scale replacement of bolts and rivets. During the war of 1939-45, Sten guns were made by 'automatic spot welding', while a total length of nearly 1600 km (1000 miles) of Pluto pipeline was put together by 198 000 welded joints. Underwater welding was used to make temporary repairs to damaged ships' hulls.⁽⁸⁾ The welding of a number of metals and alloys, including heat-resisting steels, to ensure formation of consistently strong and dependable joints while at the same time avoiding damage to the properties of the material being treated, demanded a new range of technological expertise. By the year 1950, although much progress had been made, not all of the difficulties associated with welding had been overcome.

The metallic cartridge, largely produced from solid-drawn brass, was an invention of the second half of the nineteenth century: by the Boer War of 1901, the British manufacturer George Kynoch was able to produce two-million rounds a week.⁽⁹⁾ During the period 1901 - 1950, substantial numbers of new alloys were formulated to possess particular qualities. Many of these innovations were obtained wholly empirically, either fortuitously or as the outcome of sustained and exhaustive practical exploration. In general, the new metallic materials came from demands for larger electrical generators, more-powerful aircraft, and cheaper motor cars.

Before 1851, attention had already been paid to the important matter of 'strength' and rigidity in materials and some appropriate methods for assessment had been devised. With the great increase in both the scale and the range of metals and alloys which took place during the century

(8) FOX, F.A., and HIPPERSON, A.J., 'A hundred years of progress and development in metal joining processes'. Sheet Metal Inds., vol. 28 (1951), 469.

(9) CHADWICK, R., op.cit., 631.

1851 - 1950 the subjects of mechanical testing and chemical analysis both developed considerably. In response to problems that arose due to variability of properties in metallic products, new procedures were devised to detect, and then to quantitatively determine, the proportions of elements present in raw materials, intermediates, and finished goods. Because of the financial importance of turning out products that were saleable, proprietors of metal works began to hire people able to supply information based on mechanical tests and chemical analyses, either as direct employees or as consultants. On the whole, employers regarded their own analysts as 'necessary evils': useful as tools but not to be considered as direct contributors to the main responsibilities of works' production. During the second half of the nineteenth century, the offices of the few practising consultant chemical analysts, such as William Baker ARSM in Sheffield, and John Edward Stead in Middlesbrough, afforded important means for instructing younger men in aspects of metallurgical industry.

Besides its quantitative abundance, which called for repetitious routine tests for maintenance of acceptable quality, bulk steel presented a challenge to understanding on account of the wide variations of properties that could be obtained as the result both of small changes in chemical composition and by different mechanical and heat treatments of the solid metal. Speculation about the nature and constitution of metals, as of other kinds of matter, was no new thing. However, visual observation of metallic structures by means of the microscope was not at first taken up when its features were described with direct reference to iron-carbon alloys by H.C. Sorby of Sheffield in the 1860s; it was not until twenty years later that such 'metallographic' studies began to be used as aids to understanding metals by a handful of workers spread through several countries. One of the notable British contributors to metallography was J.E. Stead of Middlesbrough.

In the 1880s too, it became possible to measure temperatures above the limits of glass thermometers and as a result investigators were able to obtain accurate information on the behaviour of metallic substances when heated and cooled. Professor W.C. Roberts-Austen of the Royal School

of Mines in London was one of the leaders of this line of enquiry, while Professor J.O. Arnold of Sheffield was active as far as the constitution of steels was concerned. Notable advances were also due to workers in France and the USA. As the outcome of joint efforts, by 1901, although some aspects remained unexplained, many of the chief features of the iron-carbon system, that is including steels, had been elucidated.

'Phase diagrams' representing the relationship between the iron and carbon components over a wide range of temperature were published before 1905. The main aspects of the theory of hardening steels by quenching and tempering were developed between 1910 and 1920,⁽¹⁰⁾ the last obscure points being resolved soon after 1920 by studying the diffraction behaviour of x rays beamed onto crystal specimens. This x-ray technique, which was introduced c.1912, enabled much new information to be deduced about the packing arrangements of atoms in solid materials.

In several ways the iron-carbon system was uncommonly complex; the same investigatory methods were applied to a host of other metallic combinations to discover the exact nature of the constituents present and their relationships. Besides Roberts-Austen, pioneer British workers included two investigators at Cambridge, C.T. Heycock and F.H. Neville, whose first thermal-equilibrium diagram, relating to gold-silver alloys, appeared in 1896. This was followed, soon after 1901, by more published results, such as those in 1903 for the copper-tin system, including bronzes, which were of remarkably-high standard.⁽¹¹⁾ Similar research to determine in detail the phases present in hundreds of alloys was pursued during the first half of the twentieth century, some results being of direct industrial significance. Among leading interpreters in this field in the quarter-century from 1925 was Dr. William Hume-Rothery who at that time returned to the University of Oxford to 'carry on research ... on intermetallic compounds and problems on the borderland of metallography and chemistry';⁽¹²⁾ in 1938, he was appointed university lecturer in metallurgical chemistry. Hume-Rothery succeeded in perceiving an ordering

(10) ALLEN, N.P., 'Fifty years' progress in the understanding of metals'. Jrnl.Birmingham Metall.Soc., (Golden Jubilee Issue), (1954), 95.

(11) HAUGHTON, John L., 'The history of equilibrium diagrams'. Jrnl.Inst.Metals, vol.73, pt.11 (1947), 697.

(12) RAYNOR, G.V., 'William Hume-Rothery 1899-1968'. Biogr.Mems. Fellows R. Soc. (London), vol.15 (1969), 112.

pattern in the alloying behaviour of combinations of elements, and propounded this in a number of publications beginning in the 1930s. Consequently it could be said that he 'demonstrated that metallurgy could be treated as a scientific discipline in its own right'.⁽¹³⁾

In the years preceding the outbreak of war in 1914, the phenomena of 'strain hardening', or strengthening of plastically-deformed metal, and annealing 'were fully examined'.⁽¹⁴⁾ Fresh opportunity for the systematic study of certain aspects of the mechanical behaviour of metallic materials came with the opening of the British Government's National Physical Laboratory soon after the turn of the century. The 'fatigue' of metals, or loss of strength after repeated changes of applied load, was one topic investigated. Further insight into the mechanism of deformation was gained by work done on carefully-prepared single crystals of material. Professor H.C.H. Carpenter was 'the first to prepare large single crystals by a process of grain growth', a published account relating to aluminium appearing in 1920, and results obtained by various workers following during the 1920s.⁽¹⁵⁾ An acceptable explanation for the observed behaviour of metallic materials was aided c.1905 by the suggestion of 'slip bands', and to this was coupled during the 1930s the idea of 'dislocations', or local irregularities in the ordered disposition of atomic layers. Supporting evidence was revealed by the greater magnifications of the new electron microscope in the closing years of the half century. By these means it became possible for theory and practical behaviour to be largely reconciled; but this exercise was incomplete in 1950, and in some quarters certain implications of dislocations were to occupy attention in the second half of the twentieth century. One 1970s' assessment is that the dislocation 'probably was metallurgy's most important contribution to science in general.'⁽¹⁶⁾

(13) RAYNOR, G.V., op.cit., 114.

(14) ALLEN, N.P., op.cit., 102.

(15) CHASTON, J.C., 'Non-ferrous metallurgy a century of British progress'. The Metal Ind., vol.71 (11 July 1947), 30.

(16) TYLECOTE, R.F., op.cit., 160.

There are two salient points that emerge clearly from this survey of the scope of metallic activity during the period 1851 - 1950. One is that metals were fundamental ingredients of the industrialised way of life which some nations, notably Britain, in 1851 were already beginning to embrace. The Great Exhibition of that year, indeed, was intended to extol and symbolise the virtues of such metal-based industrialisation. If metals were regarded as nationally important in 1851, they were in fact, although unacknowledged, of even greater importance in subsequent decades, particularly after 1910. Metals enabled the British nation to attain the outcomes it sought during the two major wars of 1914-18 and 1939-45, and in all stages of the hundred-year period 1851 - 1950 metals offered prospects of improved living conditions.

The second point that is apparent is the extensive amount of developments with metals that took place during the period under consideration. There were developments in the scale and financial value of metal production, in the methods available for processing ores to yield metals, and similarly in the ways of treating metals and alloys to produce useful articles. There was considerable enlargement in the number of alloys that consumers could obtain to fulfil an ever-widening range of duties. There was substantial progress in knowledge of the fundamental structure of metals and how this was related to their behaviour and properties. As one consequence of these last developments, metals and their study became of renewed interest to academic physicists and other philosophers.

Altogether, the materialistic 'British way of life' in 1950 would not have survived for long without its firm base of metals.

CHAPTER 2THE STATE OF METALLURGICAL INSTRUCTION IN 1851

The successful staging of the Great Exhibition in London in 1851 depended to a considerable extent upon the skill of metallurgists: Paxton's hall, in which the exhibition was housed in Hyde Park, was built of glass and cast iron. Many of the objects displayed inside Paxton's building were products of metal, overtly or otherwise, examples including: bronze statues, agricultural machinery, steam engines and other railway components, clocks and watches, cutlery, ornaments and jewellery, coinage, and optical instruments. For the creation of such objects, most of which were at the time coming into rapidly increasing use in Europe and North America, their makers drew upon two lines of skill and knowledge: that of the alchemist, and that of the smith (that is, the 'engineer' of the eighteenth-century industrial revolution). Chemical skill was needed to produce the various metals from their ores, while mechanical expertise was required to shape and work the metals and alloys to desired form, at the same time ensuring that they possessed adequate strength. Those engaged in the production of metals also needed to know something of mineralogy, and would therefore be familiar with certain features of geology.

By the middle of the nineteenth century there had developed an appreciable number of sources of information to which a metallurgist in Britain could turn for help but, significantly, there was no place within the country where a deliberate course of instruction might be obtained. That situation was to be changed with the opening, during the Great Exhibition, of the Government School of Mines in London, soon to be known as 'the Royal School of Mines'. Before then, the nearest subjects in which an aspiring student could get tuition were 'chemistry', 'mechanics' (or 'engineering'), and even in some instances 'geology', instruction in these subjects being available

at various levels, from the universities to the mechanics' institutes.

Outside Britain, a limited number of institutions was already in existence where formal instruction might be obtained. These were primarily mining schools: in some, instruction in metallurgy was provided as part of the course, while in others, metallurgy had no place at all. Table 2.1 lists the chief mining schools in existence in 1850.

Table 2.1 : Chief mining schools in existence in 1850

Country	I n s t i t u t i o n	Date of Foundation
Hungary	Mining Academy of Schemnitz	1764
Saxony	Bergakademie, Freiburg	1765 (officially)
Russia	School in St. Petersburg	c.1775
Spain	School of Mines, Madrid	1777
Mexico	Royal Mining College, Mexico City	1777
France	École des Mines, Paris	c.1780
Sweden	Mining School, Falun	1821
Silesia	Mining School, Tarnowitz	1839

Among these, pride of place is usually accorded to the Bergakademie at Freiburg, situated in a long-worked, rich mining and smelting district of Upper Saxony, the Erzgebirge (that is, Metalliferous Mountains). One of the professors at Freiburg in the latter part of the eighteenth century was A.G. Werner (b.1749-d.1817), remembered particularly for his influential position as an advocate of 'neptunist' theories of geological deposition and formation. Some students followed a three-year course, concentrating upon those subjects expected to be of most use subsequently, while others studied for shorter periods. Besides attending the public lectures, some paid for private courses with the staff. At the beginning of the nineteenth century, 'Mr. Werner in particular had pupils' from all the nations of Europe. ... there were Frenchmen, Spaniards, Poles, Prussians, Bavarians,

and one Englishman, Mr. Chenevix.'⁽¹⁾

The other well-established mining academy in central Europe was at Schemnitz, also situated in a hilly mining district, where gold and silver had been worked for 800 years.⁽²⁾ The academy had been founded c.1760, under the auspices of Maria Theresa, and in 1815 it was said to have nearly 200 students, considerably more than the number at Freiburg.⁽³⁾ In the Spanish sphere of influence, not only had a School of Mines been started in Madrid in 1777, but in the same year a Seminario Metalico (School of Metals) had been created in Mexico City, fifteen years later to become part of the Royal Mining College. The director, who prepared the curriculum, was a Spanish metallurgist who had trained at both Freiburg and Schemnitz, Don Fausto de Elhuyar, and the staff included a professor or metallurgy.⁽⁴⁾

By the middle of the century, several other mining schools had been established in Europe, such as those at St. Etienne (founded in 1816), Alais (opened in 1845), and Tarnowitz in Silesia (founded in 1839). As these establishments all seem to have been concerned with providing instruction for miners at more-or-less local level, and largely in coal-mining districts, they are not relevant to the present study.

One of the popular occupations of the nineteenth century was self analysis: almost equally popular was that of drawing comparisons between the state of affairs in Britain and in other countries. Facilities for technical instruction came in for considerable analysis. Even before 1820, one successful copper-works' proprietor, James Hussey Vivian, described some of the opportunities for technical instruction which existed on the Continent of Europe, pointing to the complete absence of anything similar here. Indeed, in preparation for entering the family business, Vivian for a short time in 1804 had himself been a student at Freiburg. Throughout the nineteenth century, and beyond, this kind of comparison continued to be made, often as propaganda to stimulate groups to action to provide instruction in Britain; in this, in the long term, the aims were at least partly successful.

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- (1) VIVIAN, J.H., 'A sketch of the plan of the mining academies of Freyberg and Schemnitz'. Trans.Roy.Geol.Soc.Cornwall, vol.1 (1818), 73.
- (2) PAUL, Wolfgang, Mining lore (Portland, Oregon: Morris Printing Co., 2nd edn. 1971), c.58.
- (3) VIVIAN, J.H., op.cit., 74-75.
- (4) MORRAL, F.R., 'The beginning of mining and metallurgical education in the New World'. Min.Engng. (New York), vol.15, no.1 (Jan.1963), 40.

One difference between conditions on the Continent and in Britain was that in many Continental countries mineral deposits belonged to the state, and it was therefore regarded as being in the national interest to provide technical instruction for those officials who worked in the mineral industries. This was certainly one reason why schools for miners and metallurgists were established many decades before anything similar appeared in Britain: such schools were provided at state expense, and the students attending them were not obliged to pay fees. By contrast, in this country, although successive sovereigns had reserved to themselves the rights to the precious metals gold and silver, and Queen Elizabeth had taken substantial practical steps to make British metal industries effective, in the period up to 1851 the British Government paid little attention to the nation's minerals, preferring to leave their exploitation to private enterprise. Consequently in Britain it was enthusiastic individuals and private finance which tended to provide such opportunities for instruction as there might be, although by mid-century the Government, through the Board of Trade, was supporting a number of Schools of Design, and also the instructive Museum of Practical Geology in London. From this latter institution, in 1851, was to branch the Royal School of Mines, and even a decade before this, in 1841, 'pupils (were) received for instruction in analytical chemistry, metallurgy, and mineralogy'.⁽⁵⁾ The British Government also acquiesced in instruction in the use and science of materials by paying the fees of lecturers at the Military Academy, Woolwich.

The dissemination of information on scientific topics by means of lectures developed appreciably during the century from 1751 to 1850, increasing from a few isolated instances to a much-larger number of occurrences affecting many more populated districts.

Following their success with medical studies, the universities of Edinburgh and Glasgow in the second half of the eighteenth century became renowned for their scientific and mathematical instruction. At both institutions, Dr. Joseph Black (1728-1799) was a leading exponent of 'applied chemistry', from whose lectures Henry, Lord Brougham obtained some of his enthusiasm for science: in Edinburgh one professor of chemistry, William Cullen, was 'a keen advocate of applied chemistry in industry and agriculture'.⁽⁶⁾

(5) CHAMBERS, T.C., Register of the associates and old students ... of the Royal School of Mines ... with historical introduction. (London: Hazel, Watson and Viney, 1896), vii.

(6) MUSSON, A.E. and ROBINSON, Eric, Science and technology in the industrial revolution. (Manchester: Manchester Univ. Press, 1969), 56.

During the same period, Dr. James Hutton of Edinburgh attained wide recognition for his geological investigations and theories. In England there were relatively few centres of learning whence industrial science emanated. In the University of Oxford, since 1693 a chemical laboratory had existed in the basement of the old Ashmolean Museum, but it was not until 1848 that 'the first college laboratory was built at Magdalen, by Charles Daubeny, Professor of Chemistry.'⁽⁷⁾ At the University of Cambridge, an honorary professorship in chemistry was first granted in 1703, a 'chemical laboratory' coming into existence a few years later,⁽⁸⁾ with similar honorary appointments being made subsequently. It was one of the interesting 'self-made' characters of the eighteenth century, Richard Watson, who, after his election to the chemistry professorship in 1764 while still in his twenties, successfully campaigned for a remuneration. In contrast with their successors in the early nineteenth century, Watson, and the Cambridge chemistry professors during the remainder of the eighteenth century, made significant contributions to the dissemination of information in the field of applied chemistry, including some aspects of metallurgy.

Watson's Chemical essays,⁽⁹⁾ contain useful information on features of metallurgical technology, such as lead smelting in Derbyshire and zinc extraction in Bristol. Richard Watson, MA, DD, FRS, Bishop of Llandaff from 1782, had been a student at Cambridge University in his youth. When he was elected professor of chemistry in his university, he self-confessedly knew nothing of the subject. (In this he was similar to Adam Sedgwick who, 50 years later, was elected to the new professorship of geology at Cambridge without his having up to that time 'turned a stone'.) However, Watson was a versatile and hard-working man, and in a little over a year he was delivering chemical lectures to crowded audiences. In his Plan of a course of chemical lectures, published in 1771, besides describing industrial processes for preparing many of the commercial chemicals of the time, he 'devoted considerable attention to the metallurgy and assaying of metals'.⁽¹⁰⁾ In the same year that his Plan appeared, Richard Watson, at the age of 34, was appointed to the university's prestigious Regius Professorship in Divinity.

(7) RUSSELL, Colin A., 'The organisation of science in England'. Open University, course AST 281: Science and the rise of technology since 1800. Unit 8. (Milton Keynes: Open Univ.Press, 1973), 28.

(8) MUSSON, A.E. and ROBINSON, Eric, op.cit., 34.

(9) WATSON, Richard, Chemical essays. 5 vols. (Cambridge and London, 1781-1787).

(10) MUSSON, A.E. and ROBINSON, Eric, op.cit., 168.

For at least another fifteen years, however, he retained his active interest in industrial chemistry and metallurgy, until eventually obliged to forsake these pleasures, apparently by ecclesiastical pressures. Before that happened, he carried out investigations on zinc and into lead smelting, and proposed ways of dealing with the 'sulphur dioxide evolved on roasting' ores. ⁽¹¹⁾

One of Watson's successors as professor of chemistry in the University of Cambridge was William Farish, whose course of lectures after 1794 touched upon metallurgical topics, as well as on the manufacture of chemicals and aspects of civil and mechanical engineering. According to the Cambridge University Calendar of 1802, during his lectures, Farish ⁽¹²⁾

'... explains the theory and practice of Mining and of Smelting metallic ores - of bringing them to nature - of converting, purifying, compounding, and separating the Metals, and the numerous and various Manufactures which depend upon them as well as the Arts which are more remotely connected with them, such as Etching and Engraving.'

The founding of the new universities of London and Durham in the 1830s brought no immediate changes to the situation regarding metallurgical instruction. At University College, London, a chair of civil engineering was filled in 1841, ⁽¹³⁾ and another post was held by Eaton Hodgkinson, an experimenter and pioneer in a field bordering onto metallurgy, the strength of materials. ⁽¹⁴⁾ From 1837 the (second) occupant of the chair of chemistry at the college was Thomas Graham (b.1805-d.1869), who held the post until his appointment, in the 1850s, as Master of the Royal Mint; before moving to University College Graham had been professor of chemistry at Anderson's Institution in Glasgow. Starting in 1845 at University College, in addition to the day-time classes, evening classes in practical chemistry were offered. At King's College, a department under the style of Civil Engineering and Science as Applied to Arts and Manufactures was opened in 1838, when J.F. Daniell was already installed as professor of chemistry. Around 1840 W.A. Miller (b.1817-d.1870) was appointed demonstrator in chemistry, and was

(11) PARTINGTON, J.R., 'Richard Watson (1737-1816)'. Chem. and Ind., (11 Sep. 1937), 820.

(12) MUSSON, A.E. and ROBINSON, Eric, op.cit., 174.

(13) BELLOT, H. Hale, University College London 1826-1926. (London:Univ.London Press, 1929), 135.

(14) BELLOT, H. Hale, op.cit., 266.

to succeed to the chair of chemistry in 1845: although always remaining a chemist, Miller became involved in investigations of a number of metallurgical problems, such as the improvement of iron-works' efficiency. In 1847, a paper on 'the manufacture of pig iron' was among those read before the college's newly-formed Engineering Society.⁽¹⁵⁾

One of the original proprietors of University College, and later (from 1842 to 1860) its treasurer, was John Taylor, a mining engineer and business-man who, in the 1820s, worked for the creation of a school for those engaged in mining. As chairman of the committee of management of University College during the 1840s and 1850s, Taylor⁽¹⁶⁾

'exercised great influence over every aspect of the college's activities, including the appointment of staff and teaching programmes during a period when the college held a pre-eminent position in the teaching of science in England.'

As early as 1823, John Taylor had delivered a course of three lectures on metallurgy at the London Institution in Finsbury Circus, a private establishment founded in the opening decade of the century 'to maintain ... an extensive general library ... and to promote the diffusion of knowledge by lectures and conversazioni'.⁽¹⁷⁾ It is interesting to speculate upon the influence that John Taylor may have had upon Albert the Prince Consort, who was to take such a leading part in promoting the creation of the Royal School of Mines in London, with its department of metallurgy. Certainly, when in 1847 the Prince Consort visited Cornwall with Queen Victoria, they were taken on a tour of underground mine workings by Taylor in his capacity as mineral agent to the Duchy of Cornwall.⁽¹⁸⁾

In the north of England, the University of Durham, founded in 1832, included a lectureship in chemistry and mineralogy and, for a few years around 1838, it also ran courses in civil engineering and mining: among the

(15) DAVIES, Professor S.J., 'Address delivered at centenary meeting of "King's College (London) Engineering Society" 1847-1947'. (King's College, London, 1947), 4.

(16) BURT, R., John Taylor: mining entrepreneur and engineer 1779-1863. (Hartington, Buxton: Moorland Publ. Co., 1977), 70.

(17) BECKER, Bernard, Scientific London. (London, H.S. King, 1874), 193-194.

(18) ANON., Centenary of the Royal School of Mines 1851-1951. (London: the School, 1951), 6.

topics to be considered by students were ' ... mineralogy; metallurgy; geology; the French, German, Italian, and Spanish languages.' ⁽¹⁹⁾ The first university lecturer in chemistry and mineralogy was J.F.W. Johnston. In 1834 one of the largest organisations concerned with the exploitation of lead in the northern Pennines, the London Lead Company, paid Johnston, '100 guineas (i.e. £105) for lectures given to all the agents and assistants at Middleton (in Teesdale) and £90 was spent on apparatus and books.' ⁽²⁰⁾

However, taken altogether, the opportunities at the universities for obtaining instruction of use to a metallurgist were meagre, and it was outside these institutions that greater developments in the provision of general scientific information took place.

A large proportion of those who engaged in scientific pursuits were medically qualified, and the schools of medicine were major sources of information and advice on chemistry, their chemical staff being involved with the solutions to numerous industrial problems, including those of a metallurgical nature. When not connected with universities, the medical schools were either supported by benefactors, or run as commercial undertakings. On occasion, a practising metallurgist might become a medical-school lecturer, as happened in the case of Dr. Edwards who, in the 1790s, was at the Hayle Copper Works in Cornwall, where he had a 'fine laboratory and library', and was visited by the youthful Humphry Davy; later, Edwards became chemical lecturer at St. Bartholomew's Hospital in London. ⁽²¹⁾ At the Sheffield Medical Institution in 1846 the lecturer in chemistry, James Haywood, apparently as a personal venture, offered a series of 50 public lectures on 'chemistry, especially as connected with agriculture, manufactures and economy'. These were to be held on three evenings a week, at a fee of £3.15 (that is, three guineas). ⁽²²⁾

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- (19) CHEVALLIER, Temple, 'Mining education at the University of Durham'. Printed statement dated 2 March 1841, addressed to the Committee for the Investigation of Accidents in Mines. (Newcastle-upon-Tyne: Bell Collection of Papers), vol.3, entry 355.
- (20) RAISTRICK, A. and JENNINGS, B., A history of lead mining in the Pennines. (London: Longmans, Green, 1965), 242; quoting records of the London Lead Company.
- (21) MUSSON, A.E. and ROBINSON, Eric, op.cit., 132; quoting PARIS, J.A., The life of Sir Humphry Davy, (1831).
- (22) INKSTER, Ian, 'The development of a scientific community in Sheffield, 1790-1850: a network of people and interests'. Trans. Hunter Archaeo.Soc. (Sheffield), vol.10,pt.2 (1973), 102.

In Newcastle-upon-Tyne in the 1840s, the lecturer in chemistry at the College of Medicine, which had been started in 1832, ⁽²³⁾ was Dr. Thomas Richardson. Richardson, who was a pupil of J.F.W. Johnston, acted as a consultant to the London Lead Company, making suggestions for improvements in technical processes. There is no doubt he was greatly interested in industrial applications of chemistry; he might be regarded as one of the earliest 'chemical engineers'. In 1845 the records of the London Lead Company state that ⁽²⁴⁾

'the most promising and intelligent of the younger clerks are sent for instruction in Chemistry, etc., to Newcastle, at such times of the year as they can best be spared, also they are occasionally sent on journeys to inform themselves by visiting other establishments'.

In some district centres there were close links between medical schools and various voluntary groups which came into being to promote the spread of information, especially during the first half of the nineteenth century. Many of these groups described themselves as 'literary and philosophical societies'. Founded in 1793, the society of that name in Newcastle-upon-Tyne ranks as one of the oldest of such bodies in Britain, and its activities may be regarded as reasonably typical of the larger groups. Among the aims proposed at the Newcastle society's foundation was that of investigating questions pertaining to the coal and lead industries of the district. It is doubtful whether much headway was made with these topics but, as a feature of policy, educational classes were started in 1803, the paid lecturer being expected to hold courses of twenty or more meetings at certain times of year. Each lecture was delivered twice: for country members at 11 o'clock in the morning, and again for town members at 8 in the evening. Fees charged for the courses in the early years were one guinea (£1.05) to ordinary members of the society, two guineas to nonmembers, and the comparatively-large sum of three shillings (£0.15) for each single lecture. ⁽²⁵⁾ A course of 32 lectures

(23) HOWDEN, Robert, 'The University of Durham College of Medicine, Newcastle-upon-Tyne'. In Official handbook to Newcastle and district, (eds.) RICHARDSON and TOMLINSON, (Newcastle: Andrew Reid, 1916), 144.

(24) RAISTRICK, A. and JENNINGS, B., loc.cit.

(25) WATSON, Robert Spence, The history of the Literary and Philosophical Society of Newcastle-upon-Tyne (1793-1896). (London: Walter Scott, 1897), 217, 216.

on 'chemistry and its applications to the arts' was given in the session 1804-05, and the opportunity for members to participate in a similar series came again in 1815-16. After this, 'chemistry' next featured in the lectures in 1824-25. For the thirty years from the inception of the scheme to 1833, the lecturer was the Revd. William Turner, a Unitarian minister in Newcastle. 'Chemistry' appeared again in 1833, but this time the series of twenty-two lectures was given by James F.W. Johnston, 'professor of chemistry' in the new University of Durham. Associated with this series, an innovation was the provision of practical classes, held in the mornings of the lecture days, from which the students 'reaped the greatest benefit'.⁽²⁶⁾

At the Newcastle 'Lit. and Phil.', 'the mineral kingdom' was first given as a series of twenty lectures by Mr. Turner in 1814, the topic occurring again in 1822-23 and 1830. In 1834 'mineralogy and geology' was offered, the lecturer for this series being John Phillips, professor of geology at the newly-formed King's College, London, who also ran practical classes in the form of excursions 'to the many geological points with which this district abounds.'⁽²⁷⁾

In subsequent years, opportunities for those within reach of Newcastle to attend lectures on chemical or geological topics recurred from time to time, although after 1840 most of the courses offered were shorter, mainly being limited to no more than two or three lectures. By the year 1896 the Newcastle 'Lit. and Phil.' was to have provided 140 courses of an educational kind, expending £18 000 'to meet certain of the educational requirements of this district'.⁽²⁸⁾

In Sheffield, a Literary and Philosophical Society was formed at the end of 1822, and in the following year £63 was paid to John Webster for twelve lectures on chemistry and mechanics, while in 1826 Richard Phillips received £150 for his twelve chemical lectures.⁽²⁹⁾

(26) WATSON, Robert Spence, op.cit., 229.

(27) WATSON, Robert Spence, op.cit., 230.

(28) WATSON, Robert Spence, op.cit., 258-259.

(29) INKSTER, Ian, op.cit., 105.

Ian Inkster, who has made a study of public scientific activity in Sheffield during the period, records that in the first half of the nineteenth century itinerant lecturers provided an important source of information and inspiration on various aspects of science. These men travelled the country to make livings by presenting courses of lectures, or sometimes one-night stands, in the centres of population. Admission to a single lecture might cost £0.05 (one shilling), a sum sufficiently large to have proved a barrier to many; for a course of twelve lectures the presenter might charge £1.05 (i.e. one guinea), and was apparently often successful in obtaining enough takers to make the exercise rewarding.

Naturally enough, the direct links with metallurgy provided by the popular science lecturers were few and far between. In Sheffield, in 1789 there was offered a course on chemistry, comprising fifteen lectures. The lecturer, John Booth, was himself connected with the iron trade, inheriting his father's iron works. He not only provided chemical lectures in Sheffield, but went to Chesterfield to repeat the course; in the following year he offered the course again in Sheffield, advertising for at least 40 subscribers to make it worth his while to begin. Around the beginning of the nineteenth century an average of between one and two lecture courses a year was presented by itinerant commercial lecturers: those on chemistry were uncommon, and those dealing with metals highly unusual. However, a course of twelve lectures on 'metals and metallurgy' was presented in 1799 by Thomas O. Warwick, at that time a dissenting minister in Rotherham. ⁽³⁰⁾ In Sheffield in 1806 a dozen lectures on 'experimental chemistry' were given by an itinerant who claimed to be 'lecturer in chemistry at the Middlesex Hospital ... London', and an 'hon. member of the Literary and Philosophical Society, Newcastle'. Parts of his course dealt with the important relationship between chemistry and commercial manufacturing. ⁽³¹⁾ In 1807 another self-made lecturer, who was involved with the practical working of metals, offered lectures in Derby, 'on the production, management and application of metals and metallic oxides'; in fact, one of the four lectures was devoted entirely to non-metallic and sensational aspects of the new galvanism. ⁽³²⁾

(30) INKSTER, Ian, op.cit., 117, 115.

(31) INKSTER, Ian, op.cit., 101.

(32) INKSTER, Ian, op.cit., 123.

Although these itinerant lecturers found it worthwhile to appeal to the public at large for support, there was a growing tendency in the towns for like-minded people to form groups to pursue their mutual interests. Thus, in Sheffield soon after the opening of the nineteenth century, there existed the Society for the Promotion of Useful Knowledge. In 1804 those attending its meetings had the opportunity to hear about the manufacture of white lead (the important ingredient of paints), and a lecture on 'Quicksilver - a general history of the metal and effects of different degrees of oxygenation'. The talk on white lead was highly technical, and suggested forming the substance by a method which would minimise workers' exposure to its effects. However, on such an occasion it seems unlikely that more than a dozen people would have been present.⁽³³⁾ Other papers presented to the Society for the Promotion of Useful Knowledge dealt with aspects of the preparation of silver from lead, and with the melting of copper. Again in Sheffield, during the greater part of the 1830s there was in being a Physical Club, with some twenty-four members. It is claimed this society was 'intended as a forum for the discussion of new inventions and techniques, and as a means of keeping up to date on scientific progress'.⁽³⁴⁾ Perhaps the nearest it came to metallurgy was in 1834, when it considered a short paper on 'The action of steam upon iron'. Even when a People's College was started in Sheffield in 1842, it had no effect upon the paucity of instruction available in technical subjects.

Besides the substantial impact on the spread of general information that was made by the literary and philosophical societies, during the second quarter of the nineteenth century another important agency was the mechanics' institutes. Commonly linked with the name of Dr. George Birkbeck, the first three of these societies were established in Edinburgh (1821), Glasgow (1823), and London (1823-24). In 1824 mechanics' institutes were opened in other towns, such as Leeds and Manchester, and by 1826 it is estimated that more than one hundred were in existence. These institutes set out to provide their members with evening lectures on scientific topics such as chemistry, astronomy, botany and physics. After the initial decade of enthusiasm, however,

(33) INKSTER, Ian, op.cit., 104.

(34) INKSTER, Ian, op.cit., 106.

demand for such subjects declined markedly, and instead, features of general education became predominant, that is to say, reading, writing, and arithmetic. For instance, in Newcastle-upon-Tyne, evening classes in chemistry were offered for a few years in the 1820s but, by 1830, they had collapsed for lack of support. (35)

The progress of the Mechanics' Institute in Sheffield will illustrate the general trend. Its forerunner was the Mechanics' and Apprentices' Library opened in the town in 1824; one year later this possessed 1100 volumes, (36) and a paper on 'chemistry as connected with the manufactures of Sheffield' was presented in association with it. (37) In 1832 there was established the Sheffield Mechanics' Institute, it being stated that there was a desire to set up an institution (38)

'to supply at a cheap rate to the working classes ...
instruction in the various branches of Science and Art which
are of practical application to their Diversified avocations
and pursuits'.

The institute attempted to provide evening classes in subjects such as drawing, grammar, geography, and natural philosophy. At the end of 1833 it made a grant of £37 for 'experiments and illustrations in electrolysis, pneumatics and chemistry'. At much the same time, a course of six lectures on geology was offered. (39)

North of Sheffield, in the new iron town of Middlesbrough, a Mechanics' Institute was formed in September 1844, when 104 members were enrolled. A year later evening classes began in reading, drawing, grammar and arithmetic; not until 1861, however, was a class in chemistry offered. (40)

(35) DYER, L. John, 'Newcastle Mechanics' Institute'. Adult Edn., vol.22 (1949-50), 123.

(36) SALT, J., 'The creation of the Sheffield Mechanics' Institute'. Vocational Aspect, vol.18, no.40 (Summer 1966), 143; quoting The Sheffield Mercury, (12 Feb.1825), 54.

(37) INKSTER, Ian, op.cit., 110.

(38) SALT, J., op.cit., 147; quoting 'The minutes of the Sheffield Mechanics' Institute', (Aug. 1832).

(39) INKSTER, Ian, op.cit., 110, 111.

(40) BUTTERWORTH, H., 'The development of technical education in Middlesbrough, 1844-1903'. Durham Rsch.Rev., vol.3, pt.2 (Sep.1960), 27.

By the year 1851, and in the space of a generation, this voluntary movement had grown to a level of some 600 institutions, with a total of between 60 000 and 102 000 members.⁽⁴¹⁾ There had also been achieved a constructive co-operation between individual institutes, one hundred of which, with a membership of nearly 20 000 individuals, had formed a union intended to be of mutual benefit, enabling systematic courses of lectures to be provided on subjects which included chemistry, economics, statistics, and applied mechanics. It is fairly clear that the mechanics' institutes never set out to provide technical instruction for trades, but rather to enunciate the principles which guided them, and to give their general scientific background. Even so, the predilection for science with which they began in the 1820s soon declined, and the institutes' sphere of influence changed. Their impact upon general education was significant, and during the third quarter of the century it was to become greater.

In marked contrast with the wide-spread mechanics' institutes which offered elements of general education during the 1840s, there were a few establishments, founded by private money, which supplied training of a more technical character. One of these was the Royal College of Chemistry, promoted by the Prince Consort and Sir James Clark (Queen Victoria's physician) with the aim of making available in Britain, to those students who could afford the fees and the time to study, tuition in chemistry at a high level. The day-time work included substantial practical exercises. A German, A.W. Hoffmann, was appointed director in 1845, and the new institution occupied premises near Oxford Street and Hanover Square. After eight years of existence, in 1853 the college was to be 'nationalised', when it was taken over by Government and added to the School of Mines.

In 1838 an engineering college in Putney was opened to students. In some respects this appears to have had similarities with the Royal College of Chemistry, but it lacked royal patronage and, although it served as the training ground for a number of youths who subsequently became successful engineers, it faded from the scene before the end of the nineteenth century.

(41) DUNSHEATH, Percy, 'Technological education'. Chapter 9 in A Century of technology 1851-1951, (ed.) P. DUNSHEATH, (London: Hutchinson's Sci. and Tech. Publns, 1951), 316.

Another privately-funded body, but of rather a different kind, was the Royal Institution in London, formed 'for diffusing the knowledge of useful mechanical improvements' and for teaching 'the application of scientific discoveries to the improvement of arts and manufactures in this country'.⁽⁴²⁾ At the beginning of the nineteenth century the Royal Institution in London's Albemarle Street was Britain's 'only public research laboratory'.⁽⁴³⁾ There, the subject of metals and their properties assumed occasional importance. The original concept of the foundation, however, became greatly altered, for 'the institution was no longer a popular school of technical science, but became almost the exclusive property of the higher classes.'⁽⁴⁴⁾

Humphry Davy was the brilliant young Cornishman who had charge of the laboratory in the early years of the century. In 1807 he successfully produced, for the first time, the metals potassium and sodium by means of the electrical energy from the new Voltaic batteries which depended entirely upon the interaction of two dissimilar metals, such as copper and zinc. Later, for several years around 1820, Davy's assistant and subsequent successor, Michael Faraday, pursued investigations into some features of metals, trying to create better 'alloys of steel'. In the course of this enquiry Faraday visited the large iron works at Dowlais in south-east Wales and, following this visit, was employed to analyse in the London laboratory a range of samples drawn from the works. While walking in Wales, Faraday called at Vivian's copper works near to Swansea, where he was allowed to see all the processes used, and this enabled him to commit a detailed account to the pages of his 'Journal'. Moreover, on his return to London, certain techniques used to harden copper were applied to his steel researches. However, Michael Faraday's investigations with 'alloys of steel' lasted only until 1823, when his commercial collaborator died, but during them he studied the crystalline structure of the specimens by etching with acid and examination under the microscope.⁽⁴⁵⁾ Later, close to 1830, at the Royal Institution Faraday carried out his great work on electromagnetic effects: work which relied absolutely upon the two metals copper and iron.

(42) BECKER, Bernard, op.cit., 32.

(43) CARDWELL, D.S.L., The organisation of science in England.
(London: Heinemann, 1972 edn.), 37.

(44) BECKER, Bernard, op.cit., 36.

(45) WILLIAMS, L. Pearce, Michael Faraday. (London: Chapman and Hall, 1965),
113.

For several decades before London's Royal Institution had appeared, the Society of Arts was in existence, having been founded in 1754. However, during its first 90 years the society seems to have done nothing of relevance to the present study, but it then came into prominence as the body which promoted the Great Exhibition in London. In subsequent years it was to take an active part in furthering certain aspects of technical instruction.

Similarly, England's premier scientific body, the Royal Society, apparently provided no help towards the spread of metallurgical knowledge during the first half of the nineteenth century, except in a negative way, and in contrast with its attitude and achievements in the latter part of the seventeenth century. It could be argued that in the first half of the nineteenth century the lack of interest in scientific progress and development shown by the society was a factor in the creation of other groups.

One such body, whose foundation is directly attributable to dissatisfaction with the Royal Society, was the British Association for the Advancement of Science. Far-less exclusive than both the Royal Society and the Royal Institution, in the twenty years between its formal establishment in 1831 at York and the middle of the century, the body had certainly shown its usefulness. By the practice of holding its annual conferences in different provincial centres, the British Association stimulated interest in science in many districts of the kingdom, encouraging the presentation of papers based upon scientific observations and affording large numbers of people with opportunities for 'contact' with science. In 1845, the renowned scientist R.W. Bunsen and the younger Lyon Playfair (then assistant chemist at the Museum of Practical Geology) presented to the British Association, meeting in Cambridge, a report of their investigations into the chemistry and working of the blast-furnace process for making iron. ⁽⁴⁶⁾ This was a significant contribution to the knowledge of a sector of metallurgical processing vital to the British economy and, consequently, to the country's dominant world position throughout the first three-quarters of the nineteenth century.

(46) BUNSEN, R.W. and PLAYFAIR, Lyon, 'The gases evolved from iron furnaces with reference to the theory of the smelting of iron'. (Cambridge: British Assocn., 1845), 142-186.

In spite of the developments that occurred in the first half of the nineteenth century, the individual metallurgist of 1851 might still have felt himself to be working in isolation: a sensation not wholly unknown a century later! Not until the second half of the nineteenth century was there any substantial growth in the establishment of professional and learned societies for technologists and engineers. Nevertheless, during the period from 1810 to 1850 significant steps in this field did take place. The Geological Society of London was established in 1807, while the Institution of Civil Engineers, with its headquarters in London, was founded in 1818: in its early years, no published reports of meetings were made, but from 1837 the Minutes of Proceedings began to be circulated, forming a vehicle for descriptions of metallurgical equipment and procedures, as well as for many other topics. In 1847 came the first meeting of the Institution of Mechanical Engineers, held in Birmingham; not until thirty years later was its base transferred to London. (47) The Chemical Society of London, founded in 1841, proved to be eminently more successful than an earlier London Chemical Society which, in 1824, had existed for only six months. (48) Practising metallurgists would have been among the members of these various bodies.

In the extreme south-west corner of Britain there grew up several institutions concerned, at least in part, with aspects of metallurgy: the Royal Geological Society of Cornwall, the Royal Institution of Cornwall (dating from 1818), and the Royal Polytechnic Society of Cornwall (founded c.1829). The Royal Geological Society of Cornwall was set up in 1814, and by 1818 had started to publish Transactions, while at the same time steps were taken, apparently ineffectually, to establish a chair for a professor of mineralogy and geology. These efforts were described by a sympathetic contemporary as the first attempt made 'to establish a mining academy', the writer going on to observe that 'our government is not so materially interested in the mineral production of the country as those of the continent, where all metals belong to the state ...'. (49) The Royal Institution of Cornwall, which included a museum in Truro as one of its important features,

(47) HADFIELD, Sir Robert A., Metallurgy and its influence on modern progress (London: Chapman and Hall, 1925), 269, 270.

(48) RUSSELL, Colin A., op.cit., 19.

(49) VIVIAN, J.H., op.cit., 71, 76.

in the second half of the century was to play an active part in promoting technical education in the Duchy. In parallel fashion, the Royal Polytechnic Society of Cornwall had technical instruction for the mineral industry as one of its chief objectives.

However, it was personal effort and expense which gave the Duchy its first trial mining school, for in 1838 Sir Charles Lemon of Carclew (b.1784-d.1868) offered to endow such a school, while undertaking for an experimental two-year period to meet the expenses of the venture. As a consequence, some classes were held in 1838 and 1839, but by the following year the attempt was judged to be a failure. As with so many other proposals, this one foundered for lack of money forthcoming to substantiate professed interest. It was not to be until after the turn of the half century that further efforts were made to provide technical instruction in Cornwall by means of regular classes.

In the English north Midlands, the Geological and Polytechnic Society of the West Riding, founded in 1837, had connexions in both Leeds and Sheffield, while west of the Pennines the Manchester Geological Society came into existence in 1838. The following year, a paper read to the Liverpool Polytechnic Society by Thomas Spencer was entitled 'An account of some experiments made ... (to discover) how far voltaic electricity may be usefully applied to the purpose of working in metal'. No similar institutions appeared further northwards in England, or in Wales, until after 1850. As with other groups already discussed, whose membership was composed largely of engineers, geologists, works' proprietors and businessmen, attendance at the meetings of these societies is likely to have been beneficial to individuals engaged in metallurgical pursuits. For example, at the meeting of the Geological and Polytechnic Society of the West Riding held in Sheffield in March 1842 there was presented a paper by Henry Hartops which described 'The effects of hot and cold air in the blast furnace, in the manufacture of iron'.⁽⁵⁰⁾ In view of Neilson's first use of heated air in Glasgow a dozen years before, this would be a topical review of an important industrial development.

By 1850 a fair amount of published information relating to metallurgy was available to those who were able both to procure copies of it, and to understand them. The greatest classical text was the De re metallica of Georgius Agricola, first published in Latin at Basle in 1556.⁽⁵¹⁾

(50) INKSTER, Ian, op.cit., 107.

(51) AGRICOLA, Georgius, De re metallica, translated from the first Latin edition of 1556 ... by H.C. HOOVER and L.H. HOOVER.
(London: The Mining Magazine, 1912), v-viii, xvi.

Because of its wealth of detail and breadth of subject matter, great interest surrounds the author of this work: Agricola (originally Georg Bauer) was in turn schoolmaster, town physician at Joachimsthal in Bohemia, city physician of Chemnitz in Saxony, and Burgomaster of the same place. The written text of De re metallica is supplemented by a large number of descriptive woodcuts, which would have provided great enlightenment to those unable to read.

German and Italian editions appeared within a few years of the Latin one, and it seems certain that the work continued to be used as a source of technical information into the latter half of the nineteenth century, although until 1912 no English edition was published.

The comprehensive character of Agricola's De re metallica tends to cause it to overshadow several other books which first appeared in print within the same century, but which confined themselves to restricted aspects of metallurgy. Thus, in 1500 there had been published the first printed metallurgical book, Nutzlich Bergbuchlein (Little book on ores), the writer of which is unknown. A second anonymous work was printed c.1520, the Probierbuchlein, or little book on assaying. These items were followed, in 1540, by De la pirotechnia of V. Biringuccio, who had been born in Siena, and who became head of the Papal foundry and munitions' supplies. This last book, a handbook for craftsmen, was concerned with the economic conduct of processes.⁽⁵²⁾ A French translation was made in 1627.

Within twenty years of the publication of De re metallica, there appeared in Prague another work, Beschreibung aller fürnematen mineralischen Ertzt und Berckwecksarten (Mineral ores and mining arts). Its author, Lazarus Ercker, was at one time superintendent of mines in the Holy Empire and Bohemia. His work recurred in German editions up to 1836, while an English translation of it was produced in 1683 by Sir John Pettus.⁽⁵³⁾ Also in England, copies of an essay on coal and its metallurgical uses by the controversial Dud Dudley were issued in London in 1665,⁽⁵⁴⁾ some fifty years after the use of coal

(52) WEST, E.G., 'Textbooks and teachers - thoughts on education of metallurgists'. Metallurgist Materials Technol't., vol.10 (Aug. 1978), 427.

(53) WEST, E.G., op.cit., 428.

(54) DUDLEY, Dud, Dud Dudley's metallum martis: or, iron made with pit-coale ... and with the same fuell to melt and fine imperfect metals, and refine perfect mettals. (London, 1665).

for smelting had been considered in the Metallica of Simon Sturtevant.⁽⁵⁵⁾
Another relevant English seventeenth-century work was the Metallographia of John Webster.⁽⁵⁶⁾

Abroad, in 1640 a Spanish priest and metallurgist, Don Alvaro Alonso Barba Toscano, published The art of metals: among other things, this book pointed to the need for a 'school of mining and metallurgical education' in the American Continent.⁽⁵⁷⁾

During the eighteenth century, it seems to have been chiefly in France that items were published that might have been of interest and use to metallurgists. For instance, in 1722 de Réaumur's L'art de convertir le fer forgé en acier ... was issued,⁽⁵⁸⁾ while in 1786 there appeared Memoirs sur le fer.⁽⁵⁹⁾ Another work with metallurgical content, Essais des mines et des métaux, which was published in Paris in 1764, was a French edition of a book first produced in German a quarter-century earlier.⁽⁶⁰⁾ There were also the volumes of the monumental Encyclopédie of Denis Diderot and J. D'Alembert, which came out between 1751 and 1772.⁽⁶¹⁾ Not only did this work have wide influence by virtue of the material it contained, but it stimulated others into copying its style, so that by the middle of the

(55) HADFIELD, Sir Robert A., op.cit., 343.

(56) WEBSTER, John, Metallographia: or, an history of metals
(London, 1671).

(57) MORRAL, F.R., op.cit., 40.

(58) REAUMUR, R.A.F. de, L'art de convertir le fer forgé en acier et l'art d'adoucir le fer fondu. (Paris, 1722).

(59) VANDERMONDE, A. BERTHOLLET, C. and MONGE, G., Memoire sur le fer, memoires de l'Academie Royale des Sciences. (1786).
Quoted by K.C. BARRACLOUGH, 'Steelmaking before Bessemer - the importance of the north east of England', Cleveland Indus.Archaeo.Soc.Rsch.Rpt., no.1 (1976), 22.

(60) SCHLUTER, C.A., Grünlicher Unterricht von Hüttenwerken nebst einen vollständigem Probier-Buch. (Braunschweig, 1738).
Quoted by R.F. TYLECOTE, A history of metallurgy, (London: The Metals Society, 1976), 142.

(61) DIDEROT, D. and D'Alembert, J., Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des metiers.
(Paris, 1762).

nineteenth century there had appeared a number of English encyclopedias, such as Luke Hebert's Engineer's and mechanic's encyclopedia of 1836, (62) which was soon eclipsed by the first edition of Dr. Andrew Ure's great Dictionary of arts, manufactures, mines This last work provided useful practical details over the range of metallurgical processing: ore dressing, chemical treatments, and subsequent shaping methods for iron and other metals. It was widely appreciated, for new editions continued to be produced until 1875-78. (63) Another series of publications including useful metallurgical content was Lardner's Cabinet Cyclopedia, which yielded three volumes dealing with 'iron, steel, tin, lead, copper and other metals' in the two decades before 1850. (64)

Valuable descriptions of British metallurgical practice were given by the Frenchman Gabriel Jars in his three volumes, Voyages métallurgiques, published in Lyon between 1774 and 1781, despite the fact that by no means all of the proprietors approached by Jars had been co-operative. (65) In 1827 there appeared another account in French, Voyage métallurgique en Angleterre, (66) followed fifteen years afterwards by a specialised article, 'Memoire sur la fabrication de l'acier en Yorkshire', published in the Annales des Mines, (67) the first volume of which had been issued at the beginning of the nineteenth century.

(62) HEBERT, Luke, Engineer's and mechanic's encyclopedia comprehending practical illustrations of the machinery and processes employed in every description of manufacture of the British Empire (London, 1836).

(63) URE, Andrew, Dictionary of arts, manufactures, mines ..., 3 vols. (London: Longmans, Green, 1st edn. 1839).

(64) HOLLAND, J., A treatise on the progressive improvement and present state of the manufactures in metal, 3 vols. (London: Longman, Green, etc.; vol. 1 1842; vol. 2 1833; vol. 3 1834). Lardner's cabinet cyclopedia series.

(65) JARS, Gabriel, Voyages métallurgiques, ou recherches et observations sur les mines et forges de fer ... en Allemagne, Suede, Norwege, Angleterre et Ecosse, 3 vols. (Lyon, 1774-1781).

(66) DUFRÉNOY, Pierre Armand and ÉLIE DE BEAUMONT, J.B.A.L.L., Voyage métallurgique en Angleterre (Paris, 1st edn. 1827)

(67) LE PLAY, F., 'Memoire sur la fabrication de l'acier en Yorkshire'. Annales des Mines, Tome 3, 4me, series (1843).

By the 1840s the enterprising technologist in Britain could have included in his library a copy of Bishop Watson's Chemical essays of the 1780s with their considerable metallurgical content, ⁽⁶⁸⁾ a copy of Dr. W. Richardson's English textbook of 1790, The chemical principles of the metallic arts ..., ⁽⁶⁹⁾ and Dr. William Pryce's volume, Mineralogia Cornubiensis ... of 1778, which had provided stimulus to Humphry Davy. ⁽⁷⁰⁾ In addition, articles relating to aspects of metallurgy were being printed in a number of English periodicals. For instance, besides many articles on mining, John Taylor contributed one 'On the smelting of tin ores in Cornwall and Devonshire' to the Transactions of the Geological Society in 1821, and two concerned with instruction to the Philosophical Magazine: 'A course of lectures on metallurgy delivered at the London Institution' (1823), and 'Prospectus for a school of mines in Cornwall' (1825). ⁽⁷¹⁾

Earlier, the Philosophical Magazine had been the vehicle for 'a remarkable series of papers' by David Mushet, which appeared spread 'over a period of more than ten years' from 1798. According to Musson and Robinson's assessment, Mushet 'demonstrated in brilliant fashion how chemistry and mineralogy could be usefully applied to iron smelting and forging.' ⁽⁷²⁾ Even in the eighteenth century, the long-established Philosophical Transactions of the Royal Society had contained material relating to metallurgy, such as a paper by Richard Watson, which was read before the society in 1777 and printed in the following year: 'Chemical experiments and observations on lead ores'. (Later, this was reprinted in Chemical essays, volume 3).

(68) WATSON, Richard, op.cit.

(69) RICHARDSON, W., The chemical principles of the metallic arts ... and a concise introduction to the study of chemistry. (Birmingham, 1790).

(70) PRYCE, William, Mineralogia Cornubiensis a treatise on minerals, mines, and mining (London: J. Phillips, 1778).

(71) Respectively, Trans.Geol.Soc., vol.5 (1821), 358-368;
Phil.Mag., vol.61 (1823), 283-291; 368-374; 448-458;
Phil.Mag., vol.66 (1825), 137-150.

(72) MUSSON, A.E. and ROBINSON, Eric, op.cit., 184-185.
The authors note that these articles were collected together and published as Papers on iron and steel in 1840.

Two other examples will serve to show that during the first half of the nineteenth century metallurgical information was becoming available for those who could read: the Annals of Philosophy in February 1823 contained 'An account of the process of copper smelting as conducted at the Hafod Copper Works, Swansea', by J.H. Vivian, while the Transactions of the Natural History Society of Northumberland, Durham and Newcastle for 1831 carried 'An account of the method of smelting lead ore and refining lead, practised in the mining districts of Northumberland, Cumberland, and Durham, in the year 1831', by H.L. Pattinson.

Moreover, by 1850 a periodical publication devoted to the mineral industry was being printed in English. Started in 1830 as The Quarterly Mining Review, from 1837 it became known as The Mining Journal, and was produced more frequently: 150 years later, Mining Journal is still published in London, where it appears every week.⁽⁷³⁾ On a more popular level, The Penny Magazine carried a number of articles describing activities in various manufacturing premises, a fair proportion of which were concerned with metallurgy. For instance, the Tyne-side lead industry was featured in 1844 in an article entitled 'A day at the Tyne factories'.⁽⁷⁴⁾

At the same period British patent specifications might have become worthwhile sources of information, repaying study by the diligent metallurgical worker, although it was not until the 1870s and 1880s that their number was to increase so greatly. Digests of patent specifications were given in the Repertory of arts and manufactures, the first volume of which appeared in 1794.

The first book on the new subject of electroplating was brought out in 1841 by Dr. Alfred Smee, FRS, whose official post was surgeon to the Bank of England.⁽⁷⁵⁾

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- (73) ANON., 'The Quarterly Mining Review: it paved the way'.
Mining Mag. (London), vol. 142, no.3 (Mar. 1980), 280-281.
- (74) ANON., 'A day at the Tyne factories'.
The Penny Mag., vol.13 (31 Aug. 1844), 337-342.
- (75) SMEE, Alfred, Elements of electro-metallurgy, or the art of working in metals by the galvanic fluid.
(London: 1841).

To summarise, by the year 1850 opportunities were available for the able and financially-supported person to obtain substantial amounts of information relevant to the practice of metallurgy by reading books and other printed material. In addition, such a person could attend classes for instruction in chemistry, mineralogy, and engineering. Classes in these subjects were provided at only a handful of places within Britain, however, but the improved communication systems which contributed to the growth of the written word also made it easier for a student to travel for study abroad at one of the existing 'mining schools'. At a more-local level, classes in chemistry were to be found in medical schools situated in the major British towns, while elementary classes in reading, writing and perhaps chemistry and mechanics, were supplied by the wide-spread mechanics' institutes. The well-provided person could also gain information from the meetings of one 'chemical' society and a number of 'geological' societies which were then in being in certain districts: Cornwall, London, Manchester, Leeds and Sheffield.

Benefit from any of the foregoing opportunities, however, required financial resources, time, and energy. For the ordinary, unendowed workman within a metal plant, the chances for improvement, either for himself or for his children, by any of these means were extremely slender.

When viewed in relation to the immense amount of activity with metals which was pursued, all of the above provisions were small. During the second half of the nineteenth century there was to be growth both in the quantity of metallurgical activity and in the provision for instruction: but not until after 1950 could the relationship between the two be regarded as even reasonably satisfactory.

CHAPTER 3THE PROVISION OF METALLURGICAL INSTRUCTION, 1851 - 1950

The year 1851 is chosen as the starting point for the survey because in Britain this was when the first regular instruction in 'metallurgy' became available at the newly-opened Government School of Mines and of Science Applied to the Arts. Apart from this facility in London, in the years immediately following the Great Exhibition means for formal tuition in the subject were non-existent so that metallurgical knowledge could be gained in only two ways: by studying works' practice either as an apprentice or a favoured relative of the proprietor; and by attending one of the small number of classes in existence abroad. During the 1850s, no more than a handful received formal instruction in metallurgy: in the succeeding ninety years, however, the opportunities grew considerably, as did the numbers using them. Apprenticeship and family connexions remained important, but as methods for acquiring technical knowledge they became supplemented by academic study. At first, instruction came to be provided at evening classes held in London and various provincial centres but, after the beginning of the twentieth century, some day-time classes also became available. While the bulk of such tuition was at elementary or intermediate levels, from the 1890s advanced-level courses associated with university degrees came into being at a growing number of places.

Stimulus to those attending the local less-advanced classes, and uniformity of standards within them, were provided by nationally-run examinations' systems, of which the earliest to make any impact was that of the Government Department of Science and Art. These metallurgy examinations attracted

277 candidates in 1880 and 686 in 1886.⁽¹⁾ Around 1880, the City and Guilds of London Institute also began work in this field. More than 65 years later, after 1945, national certificate examinations in metallurgy were introduced. As far as qualifications by school certificate were concerned, only in the single year 1931 was metallurgy among the subjects examined.⁽²⁾ By 1950 at least fifteen colleges offered courses leading to the City and Guilds' examinations in metallurgy. By that year too, examinations had been introduced by the Institution of Metallurgists.

Progress of the ordinary and higher national certificates during the first eight years of the scheme's working is shown graphically in Figure 3.1. In 1949, the 222 entries for the ordinary national certificate in metallurgy (henceforward referred to as 'ONC') amounted to 1.24 per cent. of all entrants in England and Wales, while in 1950 the 281 entries accounted for 1.4 per cent. In both years about one half of the candidates were successful, Table 3.1. Nearly twenty colleges offered courses for the ONC, while thirteen in England and Wales prepared candidates for the higher national certificate ('HNC').⁽³⁾

Table 3.1. Ordinary and higher national certificates
in metallurgy in England and Wales

Level	Year	Metallurgy			Total entries	Metallurgical candidates as proportion of total, %
		entries	successes	proportion of successes, per cent.		
ONC	1949	222	107	48.4	17 916	1.24
	1950	281	143	51.0	20 060	1.4
HNC	1949	74	59	80.0	5 861	1.26
	1950	62	42	67.7	6 944	0.9

In 1949 and 1950 no full-time courses for ordinary or higher national diplomas in metallurgy were available.

Based on MINISTRY OF EDUCATION, Education 1900 - 1950. The report of the Ministry of Education and the statistics of public education for England and Wales for the year 1950. (HMSO, 1951), Cmd. 8244, 205.

- (1) ROBERTS-AUSTEN, W.C., in ANON., Reports of the examiners on the results of the science examinations held in May and June 1886. (London: Eyre and Spottiswoode for HMSO, 1886), 32.
- (2) MUSGRAVE, P.W., Technical change the labour force and education. (Oxford, etc.: Pergamon Press, 1967), 145; quoting Board of Education Report 1931, 28.
- (3) ANON., 'A survey of the facilities for metallurgical education in England, Scotland and Wales'. Bull.Instn.Metallurgists, vol.2, no.5 (March 1950), 14-25

Hereinafter referred to as 'Survey (1950)'.

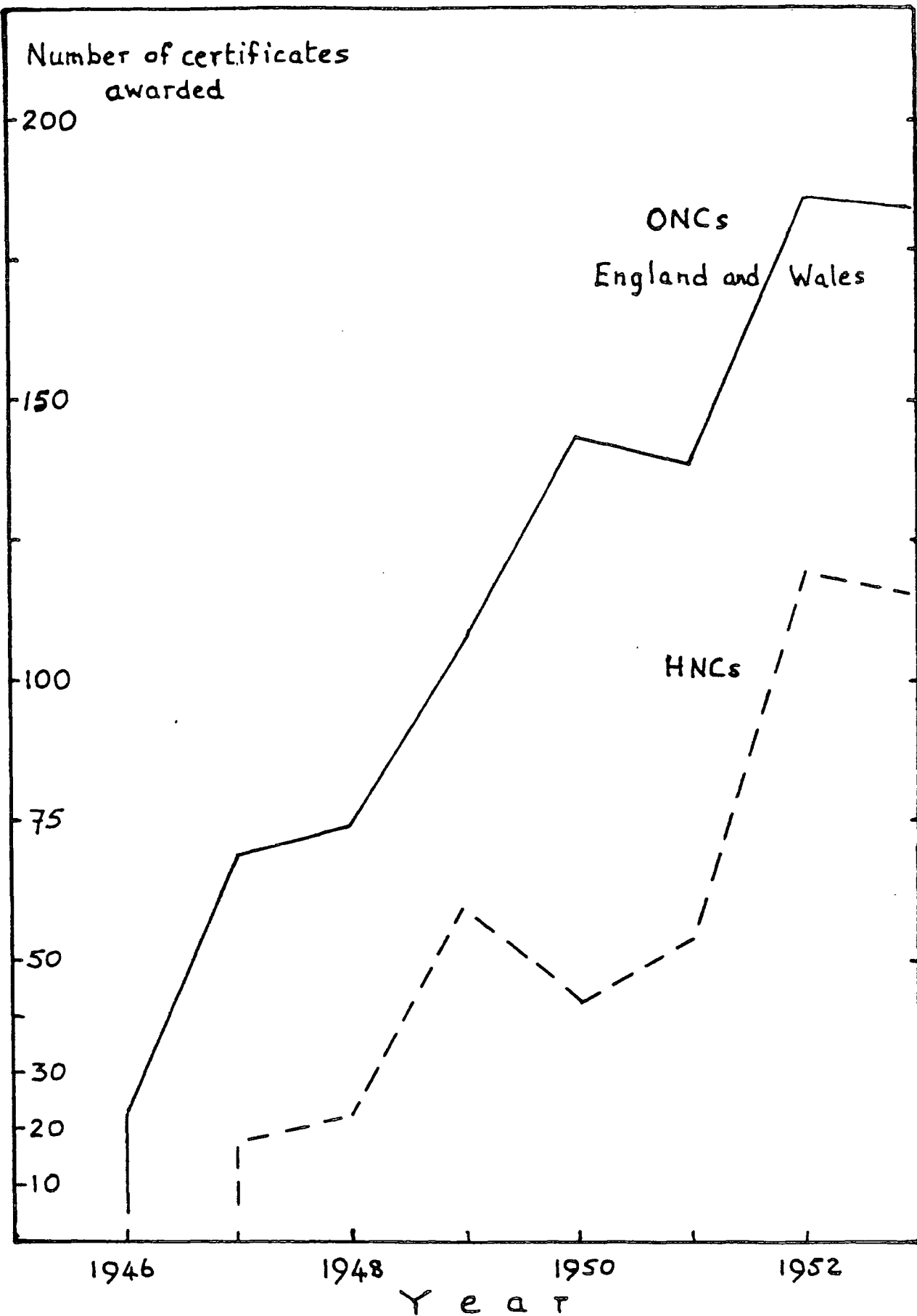


Figure 3.1. Ordinary and higher national certificates in metallurgy awarded in England and Wales, 1946 - 1953. The first ONC examinations were held in 1946, with those for HNC following in 1947.

(DUNNING, J., 'An appraisal of national certificate courses in metallurgy, on Tees-side 1957-1963'. M.Ed. thesis, Univ.Durham (1967), vol.2, 213.)

Table 3.2. The more important technical schools in 1922-23 recognised by the Board of Education as offering evening-class tuition in 'metallurgy' in England and Wales.

Location	Institution	Evening classes offered
Birmingham	Municipal Technical School	metallurgy; iron and steel
Burnley		iron and steel; metal trades
Camborne, Cornwall		metallurgy
Dudley	Municipal Technical School	metallurgy
Horwich, Lancs.	Railway Mechanics' Institute	metallurgy
Huddersfield	Technical College	metallurgy
Leeds	The Central Technical School	iron and steel; metal trades
Liverpool	Central Municipal Technical School	sheet metal work; plumbing
London	Chelsea Polytechnic	metallurgy
London	Herold's Institute, Bermondsey	metal work
Manchester	Municipal College of Technology	metallurgy; iron and steel
Middlesbrough	High School for Boys	metallurgy; iron and steel
Plymouth	Plymouth and Devonport Municipal Technical Schools	metal plate work; boilermaking; plumbing
Sheffield	Department of Applied Science, the University	metallurgy; iron and steel
Smethwick	Municipal Technical School	metallurgy
Swansea	Technical College	metallurgy; iron and steel;
Wednesbury	County Technical College	metallurgy; metal work
Wolverhampton	County Technical College	metallurgy

BOARD OF EDUCATION, List of the more important schools and of the schools of art recognised by the Board of Education under the regulations for technical, etc., schools. (HMSO, 1925), 1-39; 69-74. 'List 111'.

A quarter-century earlier, an impression of the institutions providing formal metallurgical evening-class instruction is obtainable from a survey published in 1925, Table 3.2. For some reason the Sir John Cass Institute and several other London colleges do not appear on the list. As it is doubtful whether 'metal work' is really pertinent to the present survey, for the early 1920s the number of institutions offering suitable tuition could be taken to lie between fifteen and eighteen.

Several years later, c.1930, another Board of Education publication advised that outside the university sector 'the more important centres for instruction' in metallurgy were seven, this time including Sir John Cass, Table 3.3. At the same time there were said to be nearly thirty other institutions which offered instruction.

Table 3.3. 'Important centres' for metallurgical instruction outside the university sector c.1930.

Location	Institution
Birmingham	Central Technical College
London	Sir John Cass Technical Institute
Manchester	College of Technology
Middlesbrough	Constantine Technical College
Sheffield	Applied Science Department of the University
Swansea	Technical College
Wednesbury	Technical College

BOARD OF EDUCATION, Report of H.M. inspectors on the provision of instruction in applied chemistry in technical schools and colleges in England and Wales.
(HMSO, 1931), 20.

Board of Education, educational pamphlet no. 85

At the institutions, the equipment and other facilities varied widely, from virtually nothing, through several levels of mediocrity and absence of up-to-date apparatus, to a small number of adequately equipped and laid-out premises. Around 1930 more than 1400 part-time and evening students attended

metallurgy classes which were associated with the broad subject area of 'applied chemistry'. Of these, over 1000 were pursuing 'grouped courses' involving a number of subjects, with classes planned to extend over three or even five years, while nearly 400 others were entered for 'subjects' rather than courses. Of these latter, 170 students were said to be enrolled at Sheffield for 'lectures in rolling and forging, steel melting, steel and refractories, and the production of iron and steel, provided ... for adult workers'.⁽⁴⁾

Twenty years later, at the end of the period 1851 - 1950, it seems that the equivalent numbers attending metallurgy classes had risen by between three- and four-fold, Table 3.4. It appears that in 1950 there were 4942 students enrolled for 322 'mainstream' metallurgy classes: an average of fifteen students for each class. An additional 1081 enrolments were registered for 'single-subject', or 'craft', classes in manufacture of iron, steel, and non-ferrous metals. Together, these numbers amounted to 6023 students spread among 368 classes. A further 2694 were enrolled for classes connected with foundry work, and another 2635 attended tuition in electrometallurgy, goldsmithing and dental mechanics, together making 5239 in these fringe areas. At the same time in the engineering sector, including welding, 63 467 students were on the books, while chemistry claimed the attention of 31 550.

In gauging the extent of instruction in 1950, one difficulty is to know how far to extend the boundary, from primary metallurgical classes outwards through fringe areas in which the metallurgical content, though minor, was significant. From the figures available it may be concluded that in evening classes around 15 000 people were exposed to appreciable metallurgical instruction in some form or other, while 6000 were enrolled at classes primarily devoted to an aspect of metallurgy. Compared with the evening-class entries of more than three million recorded for the year, the figure of 6000 only amounts to 0.2 per cent., yet clearly it represents a substantial advance compared with the situation that prevailed a century earlier, when virtually no classes whatsoever existed.

(4) BOARD OF EDUCATION, Report of H.M. inspectors on the provision of instruction in applied chemistry in technical schools and colleges in England and Wales. (HMSO, 1931), 25.
Board of Education, educational pamphlet no. 85.

Table 3.4. Officially-registered evening classes and students
in 1950 in England and Wales

Subject area	Number of classes registered	Number of class entries	
		other than engineering	in engineering
metallurgy (general)	313	4772	
metallurgy (non-ferrous)	<u>9</u>	<u>170</u>	
	322	4942	
iron and steel manufacture	38	996	
non-ferrous metals manufacture	<u>8</u>	<u>85</u>	
	368	6023	
foundry practice	106	1375	
pattern making and moulding	90	1319	
electrochemistry and electrometallurgy	32	464	
goldsmiths' and silversmith's work	9	316	
dental mechanics' work	<u>89</u>	<u>1855</u>	
	694	11 352	
welding	823		12 507
miscellaneous engineering and metal trades	98		1 777
metal plate work	283		4 288
machine-shop practice	1499		25 008
mechanical engineering	973		<u>19 887</u>
			63 467
chemistry	1750	31 550	

Based on MINISTRY OF EDUCATION, Education 1900-1950. The report of the Ministry of Education and the statistics of public education for England and Wales for the year 1950. (HMSO, 1951), Cmd. 8244, Table 38, 188-195.

During the 1850s, stimulated by the lead given by the Government School of Mines in London, attempts were made to establish similar institutions in other parts of Britain, but for another thirty years few were successful. In Newcastle-upon-Tyne a 'mining and manufacturing' college was proposed, while in Cornwall a similar development was mooted for Truro.⁽⁵⁾ These schemes did not come to fruition at the time but in Truro, under the auspices of the Royal Institution of Cornwall, a course of 'practical instruction in metallurgic chemistry' was advertised to commence in January 1859, and it is possible that equivalent classes of an elementary nature were offered even before this in the mining districts of the Duchy. Subsequently Cornish opportunities for instruction in metallurgy increased as 'schools of mines' were created, although after about 1910 only that at Camborne remained active.

At Bristol, a Mining and Trade School opened in 1856, and in the next few years offered laboratory practice as part of its courses: according to the 1860 syllabus this consisted of chemical analysis and mineral assaying.⁽⁶⁾ At the Bristol school a course of twenty-two lectures advertised for the first half of 1859 included, among a variety on mining topics, a single one on 'smelting ores'.⁽⁷⁾ In due course the school became absorbed in the Merchant Venturers' College, started in 1894; in this institution some metallurgy must have been taught as an incidental to engineering courses, and in 1949 it was the only centre in the south-west of England to provide instruction for the ONC in metallurgy. At this later date, complementary tuition in the south-west region was offered by the North Gloucestershire Technical College in Cheltenham, with a course of metallurgy as an endorsement subject in the HNC in mechanical engineering.⁽⁸⁾

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- (5) COUCH, R.Q. and others, 'Proposed school of mines and of science applied to the arts'. (Truro, 17 Oct. 1853).
Notice in possession of Geological Museum, London.
- (6) ANON., 'The School of Mines, Bristol. Course of lectures for the first part of the session of 1860.' (Bristol, 17 March 1860).
Printed notice in possession of Geological Museum, London.
- (7) ANON., 'Bristol Mining School. Course of lectures'.
(Bristol, 11 Jan. 1858). Printed notice in possession of Geological Museum, London.
- (8) Survey (1950), 19.

In neighbouring South Wales, at Neath in 1857 there was an unsuccessful commercial attempt to found a college 'to complete the instruction of young men in the practical application of the sciences to various pursuits'; in its more-optimistic moments, this institution advertised prospective courses which included 'mining and metallic manufactures'.⁽⁹⁾ Although in the 1860s the view was aired that it would be desirable for South Wales to possess an institution for technical instruction, nothing materialised until after 1880. Then, and during the succeeding 70 years, substantial progress was made so that by 1949 metallurgical courses in Wales, leading either to certificates of the City and Guilds of London Institute or to ONCs, were available at Llanelly, Neath, Newport, Crumlin, Swansea Technical College, and Shotton in North Wales.⁽¹⁰⁾

Turning to the Midlands, it seems clear that here, as in other parts of Britain, opportunities to obtain organised technical instruction of any kind were few and far between, at any rate for the first three decades after 1851. Institutes providing elementary general tuition were opened in connexion with ironworks at Coalbrookdale and Broseley in Shropshire in the 1860s, and at Butterley near the Derbyshire-Nottinghamshire border in 1869. Birmingham was the earliest centre for developments in metallurgical instruction; when the Birmingham and Midland Institute of Industrial Education opened in 1853, metallurgy was clearly specified as one of the subjects to be included in its school of industrial science. It is unlikely, however, that any appreciable amount of information directly relating to the subject was obtainable for the first twenty-five years. The institute's impact upon the 'artisans' for whom it was supposed to be intended was not great, and until 1880 any students who aspired to advanced courses had to look for them elsewhere; after that date the Mason Science College in Birmingham provided classes in 'pure' science and mathematics. Meanwhile, in 1875, at the

(9) ANON., 'Gnoll College, to be incorporated as the Western University of Great Britain ...'.
Advertisement, dated from Gnoll College, Vale of Neath,
Sep. 1857.
Unidentified newspaper clipping in possession of Geological
Museum, London.

(10) Survey (1950), 17.

Birmingham and Midland Institute attempts were made to establish metallurgy classes, but the poor response apparently led to their abandonment after about three years' trial.⁽¹¹⁾ However, in 1881-82 practical metallurgy, presumably intended to prepare candidates for the examinations of the Science and Art Department, was taught to six students in makeshift premises by one of the institute's full-time staff, Arthur Hiorns, recently described as 'the first designated lecturer in metallurgy outside London'.⁽¹²⁾ Shortly afterwards, new buildings were made available to the Midland Institute and these housed a school of metallurgy which was officially inaugurated in September 1885 and occupied three basement rooms, one equipped as a laboratory suitable for twenty-three students. In 1891, together with other classes administered by the Midland Institute, the school of metallurgy was transferred to the city authority, and a few years later it was incorporated in the Birmingham Municipal Technical School. Here, during the first half of the twentieth century, evening-class tuition continued to be provided at elementary and intermediate levels, while at advanced level students were prepared for the external degrees of London University.

In Birmingham the other important developments in technical education occurred at the Mason Science College, founded in 1875. In 1883 there was appointed a demonstrator in chemistry, Thomas Turner, ARSM; three years later, when Turner was promoted to 'an independent lectureship' of the department of chemistry, formal instruction in metallurgy began.⁽¹³⁾ Sixty years onwards, in 1949, in the area of the West Midlands Advisory Council there were no less than seven technical colleges providing instruction for a total of some 600 students for ONCs in metallurgy. Besides the Central Technical College in Birmingham these institutions included technical colleges in Coventry, Smethwick, Wolverhampton, and Stoke-on-Trent. At the same date HNC courses

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- (11) ANON., 'A pioneer of metallurgical education' (G.H. Kenrick). Metal Treatment, vol.33, no.247 (Apr.1966), 149; quoting WATERHOUSE, R., The Birmingham and Midland Institute, 1854-1954, (Birmingham: the Institute, 1954), 80.
- (12) NICHOLSON, O.P., The origins and history of metallurgy at Aston 1881 - 1981. (Birmingham: Univ. of Aston, 1981), 2.
- (13) TURNER, T., 'University of Birmingham'. Contribution to CARPENTER, H.C.H., 'Metallurgical education of university rank in Britain'. Proc. (1st) Empire Mining Metall. Congress, part 5, non-ferrous metallurgy. (London, 1925), 56-57.
- Hereafter referred to as 'Carpenter (1924)'.

were available at the Central Technical College, in Wolverhampton, and at Rugby Technical College, while Institution of Metallurgists' qualifications were the object of courses at Coventry and Wednesbury. All the technical colleges in the area offered metallurgy as an endorsement subject for the HNC in mechanical engineering.⁽¹⁴⁾ At Wolverhampton a National Foundry College was in existence, and a Foundry Craftsmanship Training Centre was opened in West Bromwich.⁽¹⁵⁾ Metallurgically, the West Midlands region was the most active in Britain.

In Greater London, evening metallurgy classes were available during the second half of the nineteenth century at the Royal School of Mines and at King's College. They were begun at Woolwich Arsenal around 1880, and after 1901 they were offered at three different places, Chelsea Polytechnic, the Northampton Institute, and the Sir John Cass Institute. After 1940 the metallurgical work at Chelsea was transferred to the Battersea Polytechnic, which in 1949 accounted for sixteen of the region's eighteen students for HNC in metallurgy, as well as thirty of the 58 candidates for City and Guilds' qualifications.⁽¹⁶⁾ At the same date Northampton Polytechnic had twenty students preparing for City and Guilds' examinations.

Elsewhere, in the geographical context of England south of Manchester, in 1949 courses in foundry practice were held at North Bedfordshire College of Further Education and at Ipswich School of Technology. Metallurgy for HNCs in mechanical engineering was available at Swindon Technical College, Oxford Technical College, and University College Southampton, while courses for lower standards of qualifications were provided in Norwich, Ipswich, Chelmsford, Luton, Slough and Portsmouth.⁽¹⁷⁾ In the East Midlands region, where there were nineteen technical colleges, metallurgy was taught in ten,

(14) Survey (1950), 20.

(15) O'NEILL, Hugh, 'Metallurgical education in Great Britain'.
Bull.Instn.Metallurgists, vol.2, no.2 (May 1949), 19-20.

(16) Survey (1950), 24.

(17) Survey (1950), 18-19.

but only in the case of five were the courses intended to lead directly to ONCs in this subject: at Chesterfield, Corby, Derby, Nottingham and Scunthorpe. More-advanced courses were offered at Chesterfield, Loughborough and Nottingham.⁽¹⁸⁾

In Manchester, the historic Mechanics' Institution of 1824 was re-cast soon after 1880 into the Technical School, with specialised courses of instruction for day students in applied chemistry, engineering, and the textile industries.⁽¹⁹⁾ Evening metallurgical tuition was offered in 1886, a 'full day course' being introduced ten years later within the department of applied chemistry.⁽²⁰⁾ In 1906 the then Manchester Municipal College of Technology became a constituent college of the University of Manchester, which itself had grown from the Owen's College founded in 1851. Here there is evidence that 'some lectures on metallurgical subjects' were given before 1886, at which date a chair of chemistry and metallurgy was filled; some time afterwards, a lecturer in metallurgy and fuel was appointed, and in 1906 the lectureship was translated into a professorship.⁽²¹⁾ Although at advanced levels the University of Manchester and the Manchester College of Technology continued to provide metallurgical instruction leading to B.Sc. degrees, and the latter also offered three-year part-time diplomas, at lower levels the study of the subject did not flourish in the district to the same extent that it did around Birmingham or in the East Midlands. In 1949, in the North-west region, metallurgy was taught only as part of the scheme for ONCs in engineering, at colleges in Barrow-in-Furness, Accrington, Bolton, Crewe, Oldham and Preston.⁽²²⁾

East of the Pennines, it has to be stated of Sheffield that, despite attempts made to set up a technical school in the town in 1862, and again in

(18) Survey (1950), 21.

(19) REYNOLDS, J.H., 'The origins and development of technical education in the City of Manchester'.
Old Owensian Jrnl., vol.2, no.1 (May 1924), 9.

(20) RHEAD, E.L., 'Municipal College of Technology, Manchester'.
A section of Carpenter (1924), 67.

(21) THOMPSON, F.C., 'The metallurgical department of the University of Manchester'. Bull.Instn.Metallurgists, vol.2, no.6 (May 1950), 17.

(22) Survey (1950), 22-23.

the early 1870s, the district's first successful formal metallurgical instruction seems to have been contained in classes held at the Technical School in the session 1884-85, just after the founding of 'chairs of metallurgy and engineering in connexion with Firth College'.⁽²³⁾ In some respects, however, the Technical School in Sheffield remained distinct from Firth College, and it was administered by a separate committee.⁽²⁴⁾ When in 1889 W.H. Greenwood, the original professor of metallurgy with engineering, was succeeded in the chair of metallurgy by J.O. Arnold, the new teacher 'delivered his first lecture to a single student', or so he later claimed.⁽²⁵⁾ In the Sheffield district as a whole, by 1949 technical colleges in Sheffield and Rotherham provided courses for the ONC and HNC in metallurgy, while further northwards courses for the ONC were offered at Leeds, Scunthorpe and Middlesbrough, with courses leading to HNC available at the Constantine Technical College in Middlesbrough. In Doncaster, a general metallurgical course was provided for engineers.⁽²⁶⁾

In the iron town of Middlesbrough, where the mechanics' institute had been started in 1844, classes in chemistry were held in 1861, and twenty years later, around 1880, new chemical laboratories were approved by the inspector of the Science and Art Department.⁽²⁷⁾ Soon the high-school authorities took an increasing proportion of the evening-class work from the institute. However, further development was slow, so that not until 1929 were the evening technical classes transferred to new premises, which were formally opened the following year as the Constantine Technical College; 'metallurgy and science' comprised one of the original departments. By 1949 the college offered metallurgical instruction for the City and Guilds' examinations, for the ONC and HNC, and for the external degree of the University of London.

(23) ANON., Souvenir of the ... new ... laboratories (at Sheffield University). (Sheffield: the University, 1905), 7.
Copy in possession of Mr. K.C. Barraclough.

(24) THOMAS, D.H., 'The development of technical education in England 1851-1889 ...'. Ph.D. thesis, Econ.Hist., Univ.London, (1940), 70; 71-72.

(25) ARNOLD, J.O., in discussion of JENKINS, H.C., 'The equipment of laboratories for advanced teaching and research in the mineral industries'. Trans.Instn.Min.Metall., vol.13 (1903-04), 306.

(26) Survey (1950), 21-22.

(27) BUTTERWORTH, H., 'The development of technical education in Middlesbrough, 1844-1903'. Durham Research Rev., vol. 3, pt.2 (Sep.1960), 29.

To the north, in Newcastle-upon-Tyne, the College of Physical Science opened in 1871 as a venture to provide regular classes in science. At that time the college could claim that its only English precedents were the Owen's College in Manchester and several colleges in London, for instance, King's College in the Strand. On the western outskirts of Newcastle-upon-Tyne at Elswick, around 1880 'special instruction in the metallurgy of iron and steel' was obtainable at a class organised by the industrialist Sir William Armstrong.⁽²⁸⁾ Not for some years, however, was metallurgy included in the curriculum at the Newcastle college, although in 1889 it was stated that 'chemistry, including some branches of technical chemistry and metallurgy, mineralogy, geology' were among the subjects taught. There were in addition in the 'technical department' classes in plumbing 'associated with the Worshipful Company of Plumbers of the City of London'.⁽²⁹⁾ The principal's report for 1889 commented on the need for 'a department of metallurgy', stating that⁽³⁰⁾

'The provision in this country for the efficient teaching of this subject is extremely limited, and it is believed that a well equipped Metallurgical Laboratory would be of great service to the district.'

The first metallurgy lecture course was instituted in 1891 as a part of chemistry tuition at the college;⁽³¹⁾ the following year it was stated that 'Complete courses of instruction are provided for ... metallurgists and chemical manufacturers'.⁽³²⁾ Meanwhile instruction in various subjects at elementary levels was provided at the Rutherford Technical College, which

(28) HUXLEY, T.H., as witness before the Technical Instruction Commission, Oct. 1882. Brit.Parl.Papers (1884), (31), item 3005; reproduced by RUSSELL, C.A. and GOODMAN, D.C. (eds.) in Science and the rise of technology since 1800. (Open Univ.Press, 1972), 154.

(29) ANON., Principal's report on eighteenth session, 1889, (at Durham College of Science, Newcastle-upon-Tyne). (Newcastle-upon-Tyne: Andrew Reid, no date), 1.

(30) ANON., Principal's report ..., op.cit., 5.

(31) MAXWELL, D., personal communication, 1980.

(32) MERIVALE, J.H., 'The education of mining engineers'. Trans.Instn.Min.Engrs., vol.5 (1892-93), 628.

sprang from the Science and Art School opened in 1877, extended in 1885, and removed to fresh buildings on a new site in the early 1890s. Some 55 years later, in 1949, the Rutherford Technical College in Newcastle was in process of being equipped to offer an ONC course in metallurgy. At the same date, over on the west coast of Cumbria, such a course was already available at the Cumberland Technical College in Workington.⁽³³⁾

Northwards, across the border in Scotland, immediately following his appointment in 1884 to the chair of chemistry at the College of Science and Arts in Glasgow, A.H. Sexton, ARSM, 'added metallurgy and mineralogy to the subjects taught'.⁽³⁴⁾ Shortly afterwards, on the formation of the Glasgow and West of Scotland Technical College from earlier components which included both the College of Science and the Andersonian University, Sexton became head of a new department of metallurgy and mineralogy. In 1894 the college diploma was given in subjects which included metallurgy. Later, in addition to the classes aimed at metallurgical qualifications, instruction in the subject was offered to students of chemistry, mining, and mechanical engineering.

To the north-east, in Edinburgh, in 1882-83 limited instruction in metallurgical topics was included in the chemistry syllabus of the Watt Institution and School of Arts.⁽³⁵⁾ Twenty years later the Calendar recorded the success of one student, Alexander Gray, in obtaining a First Class Pass in advanced metallurgy in the 'Science and Art and City and Guilds of London Institute Examinations, 1903'.⁽³⁶⁾ For the session 1912-13 students of mining at the college received a course of lectures on 'elementary metallurgical chemistry', as well as instruction in assaying and,⁽³⁷⁾ ten years afterwards, for the first time courses in metallurgy became listed among the day classes. Although subsequently metallurgical tuition continued to

(33) Survey (1950), 23.

(34) SEXTON, A.H., The first technical college.
(London: Chapman and Hall, 1894), 114-115.

(35) ANDERSON, A., personal communication, 1980; quoting Calendar, 1882-83, 106.

(36) ANDERSON, A., personal communication, 1980; quoting Calendar, 1903-04, 296.

(37) ANDERSON, A., personal communication, 1980; quoting Calendar, 1912-13, 86.

be provided in the Heriot-Watt College, the subject remained a subordinate one within the department of chemistry, and appeared as one of the six branches of applied chemistry in which students might specialise in the last year of the four-year diploma course.⁽³⁸⁾ In Scotland at the end of the 1940s, metallurgical instruction for the ONC and HNC was offered in the technical colleges at Coatbridge and Paisley, and at the Royal Technical College in Glasgow. At Heriot-Watt College, metallurgy appeared as an endorsement subject for the HNC in engineering. In Aberdeen, the subject formed a minor portion of engineering degree and diploma courses.

So far, this survey of facilities for formal metallurgical instruction has concentrated on levels extending up to HNC. In addition to these, it is necessary to consider what was available at more 'advanced' levels. It is to be noted that, in general, during the progress of the hundred-year period academic standards became higher as the subject, and the surrounding society, developed; thus standards that before 1901 were regarded as satisfactory for 'degree level' are unlikely in 1950 to have proved acceptable for such qualifications. In contrast with the 1850s, when the numbers successfully completing the Associateship course in metallurgy at the London School of Mines could be counted on one hand, by the late 1920s and in the 1930s full-time degree-level metallurgy students in Britain numbered perhaps 100 at any one time, with a graduation rate of between ten and twenty-two a year; after 1945 the numbers increased substantially to more than 75 a year in the period 1947-49, Figure 3.2. Thus there was a four-fold increase between 1930 and 1950; during the latter 1950s the number graduating was to increase further to reach 185 in 1961-62. In the 1930s metallurgy graduates accounted for less than one-half per cent. of all British honours graduates and about three per cent. of the corresponding numbers graduating in chemistry and engineering together. In the years around 1950 however, the proportion of metallurgy graduates rose to about one per cent. of all honours graduates,

(38) Survey (1950), 16.

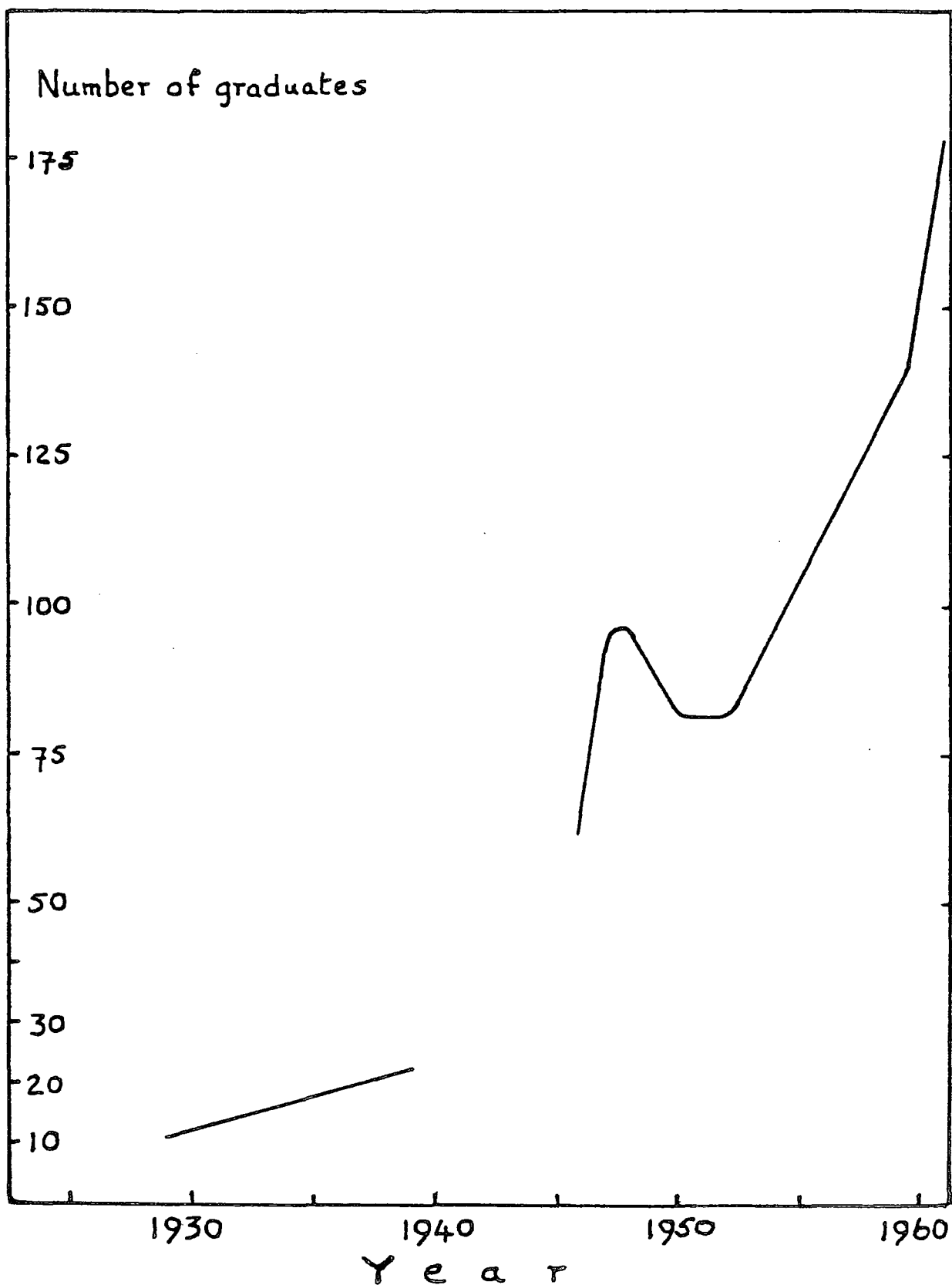


Figure 3.2. Honours degrees in metallurgy awarded in England and Wales in the years 1928 - 1960.

(UNIVERSITY GRANTS COMMITTEE, Returns from universities and university colleges in receipt of treasury grant ... for appropriate years. These returns do not provide information for years before 1928, or for the period between 1938 and 1948.)

and to about eight per cent. of the chemistry and engineering total.⁽³⁹⁾

By 1851, courses in both mechanical engineering and technical chemistry had become established in Britain at the highest academic levels then recognised, and during subsequent decades these proliferated and expanded to a greater extent than did metallurgy courses. Even at the end of the period under review, there were to be found universities and technical colleges in which 'metallurgy' was regarded only as a subordinate section within a department of chemistry or engineering.

In most instances, the courses of advanced tuition grew from earlier elementary classes. These preceding courses were provided at a number of regional centres and a high proportion seem to have been formed during the last two decades of the nineteenth century. Thus, in Sheffield the Technical School offered metallurgical instruction from 1884; in Birmingham a metallurgical lectureship was attached to the department of chemistry in the Mason Science College in 1886, while at about the same time the Midland Institute in the city started a 'school of metallurgy'. Also in 1886 a chair of metallurgy with mineralogy was created at the Glasgow and West of Scotland Technical College. Five years later, in Newcastle-upon-Tyne a metallurgical laboratory was built,⁽⁴⁰⁾ and lectures in metallurgy, as part of the chemistry course, were instituted at the Durham College of Science in the city.

The metallurgical classes available in the university departments and their equivalents were reviewed on several occasions: in 1892, 1924, 1937, 1940 and 1948. Even so, it is not easy to present a detailed, comprehensive picture of the instruction given, the qualifications achieved, and the numbers attending, although it can be stated with fair certainty when instruction in metallurgy was first offered at the various institutions, when the first metallurgical teaching staff were appointed, and when 'professorships' were established. Such information has been put on record by Carpenter (1924) and O'Neill (1948).⁽⁴¹⁾ Beyond that, however, and

(39) UNIVERSITY GRANTS COMMITTEE, Returns from universities and university colleges in receipt of treasury grant ... (various years). (HMSO, publication date one year after end of session to which report refers.)

(40) Carpenter (1924), 61.

(41) Carpenter (1924), 43-79;

O'NEILL, Hugh, 'University metallurgical training in Britain' Bull.Instn.Metallurgists, no.6 (Sep.1948), 22-29.

particularly in the earlier years, there is uncertainty about the precise dates when students first enrolled for the courses, and when qualifications in metallurgy equivalent in standard to B.Sc. degrees were awarded. Not until after about 1895 did it become possible for a degree to be obtained for studies which included a fair proportion of metallurgy. Information is summarised in Table 3.5, and presented diagrammatically in Figure 3.3.

A survey published in 1892 lists as the four places which then offered 'advanced instruction' in metallurgy: the Royal School of Mines in London, Sheffield Technical School, Camborne School of Mines in Cornwall, and the Durham College of Science in Newcastle-upon-Tyne.⁽⁴²⁾ The Associateship of the Royal School of Mines, awarded for satisfactory completion of the day-time courses at the school, was commonly regarded as a qualification equivalent in standard to the B.Sc. degree. In 1880 there were eleven Associateships in metallurgy alone, with a further three awarded in both metallurgy and mining.⁽⁴³⁾ A decade later there were fifteen Associateships in metallurgy.⁽⁴⁴⁾ At the Sheffield Technical School, Associateship diplomas were first bestowed in 1893, when one day student secured the 'blue ribbon' in company with two evening-class students. During the first four years of the Associateship course, 1893-1896, a total of six day students and three evening students passed the final examination;⁽⁴⁵⁾ by 1905, twenty day students and nineteen evening ones had gained the Associateship.⁽⁴⁶⁾ Even allowing for the fact that the 1892 list's compiler, the professor of mining at the Durham College in Newcastle-upon-Tyne, was likely to be

- (42) MERIVALE, J.H., 'The education of mining engineers'.
Trans.Instn.Min.Engrs., vol.5 (1892-93), 626-630.
- (43) ANON., Iron, vol.16 (16 July 1880), 61.
- (44) ANON., 'Technical education at the Royal College of Science, South Kensington'. The Engineer (10 Feb. 1893), 115.
- (45) ARNOLD, J.O. in discussion of REDMAYNE, R.A.S., 'The mining department of the University of Birmingham'.
Trans.Instn.Min.Engrs., vol.28 (1904-05), 506.
- (46) ARNOLD, J.O., 'The department of iron and steel metallurgy at the University of Sheffield'.
Jrnl.Iron Steel Inst., vol.58 (1905), no.2, 14.

Royal School of Mines, London

King's College, London

Sheffield, Technical School - Univ.

Birmingham, Mason College - Univ.

Glasgow, West of Scotland Tech. - Royal Ted. Coll.

Newcastle, (Univ. Durham) Armstrong / King's College

Cardiff, Univ. College - Univ. Wales

Manchester, University

Manchester, Municipal Coll. Technology

Leeds, University

Swansea, Univ. College - Univ. Wales

Liverpool, University

Cambridge, University

Oxford, Univ.

Nottingham, Univ.

London University conducted examinations
during the latter part of the period

1850 1870 1890 1910 1930 1950
Year

Figure 3.3. Courses in metallurgy associated with university degrees, 1851 - 1950. Period of definite metallurgy instruction shown by open bars; period of first degrees indicated by solid bars.

Table 3.5. British institutions in the period 1851-1950 which offered advanced qualifications in metallurgy, with their dates of inception.

Name of Institution	Year in which regular instruction in metallurgy was first offered	Year in which qualifications in metallurgy equivalent in standard to B.Sc. degree became available	Remarks
London, Royal School of Mines (Government School of Mines until 1863; part of Imperial College from 1907)	1851	1851	Associateships awarded to day students. Common examinations with University of London from 1926 for B.Sc.(Eng) degree
London, King's College	1879	?	Department closed in 1919 on retirement of professor of metallurgy
London, the University	-	c.1910	London University's examinations for 'external' as well as 'internal' candidates provided a qualifying avenue for people from all parts of Britain, and abroad
Sheffield Technical School (later University of Sheffield)	1884	1905	Associateships first awarded 1893 on result of three-year course
Birmingham, Mason College (later University of Birmingham)	1886	1902	The Birmingham and Midland Institute also provided regular instruction from c.1885
Glasgow, West of Scotland Technical College (later Royal Technical College)	1886	?	Diplomas awarded from 1894; later Associateship of Royal Technical College, ARTC. Affiliation with University of Glasgow in 1913; award of B.Sc. degree 1915

/continued ...

Name of Institution	Year in which regular instruction ... offered	Year in which ... B.Sc. degree ... available	Remarks
Glasgow, the University	1899	1915	Metallurgical lectureship in department of chemistry lapsed c.1930
Newcastle-upon-Tyne, Durham College of Science (later King's College, University of Durham)	1891-92	1894 (in chemistry department)	First B.Sc. 1897
Cardiff, University College (constituent college of University of Wales)	1894	1898	First B.Sc. graduate in metallurgy, 1903
Manchester, Owen's College (later University of Manchester)	1886 ?	1906	Post-graduate research more important than undergraduate courses until 1919
Manchester, Municipal Technical College	c.1886	1906	Affiliated to University of Manchester; B.Sc.(Tech.) of University awarded
Leeds, the University	1907	1908	Joint fuel-metallurgy degrees and diplomas
Cambridge, the University	1908	1938	Research work done since 1888. Readership established 1908
Swansea, University College (constituent college of University of Wales)	1920 ?	1920	
Liverpool, the University	1907 ?	1920	B.Eng. in metallurgy awarded
Oxford, the University	c.1938	after 1950	
Nottingham, the University	1949	after 1950	Lecturer appointed in 1949

Based on O'NEILL, Hugh, 'University metallurgical training in Britain'.
Bull.Instn.Metallurgists, no.6 (Sep. 1948), 23-26.

Comment on University of Manchester from THOMPSON, F.C., 'The metallurgical
department of the University of Manchester'.

Bull.Instn.Metallurgists, vol.2, no.6 (May 1950), 18.

prejudiced, the exclusion of the colleges in Birmingham and Glasgow may be taken as evidence that the amount of metallurgical activity pursued in them was relatively small. However, only two years later, in 1894, it was stated of Glasgow that among other subjects the college diploma was given in metallurgy.⁽⁴⁷⁾ In the neighbouring University of Glasgow, a lectureship in metallurgical chemistry was instituted in 1899.

At the Camborne School of Mines, throughout the first half of the twentieth century metallurgical instruction remained an integral, although minor, part of the courses for the mining Associateship; those of the school's students who sought the award of B.Sc. degrees had to sit separate examinations as 'external' students. The Camborne School is not considered further here.

In Newcastle-upon-Tyne in 1894 a three-year course, with a high metallurgical content, was established for the degree of B.Sc. (Durham). Moreover, one student, George Plunkett Chaplin, graduated B.Sc. in 1897 with honours in metallurgy, but he seems to have been singular. In those years the subject of metallurgy lay within the chemistry department: it was transferred in 1901 to the mining department,⁽⁴⁸⁾ under whose direction it was to stay for more than thirty years. In 1913, at a time when there were similar moves elsewhere, for example at the Royal School of Mines, to establish higher standards by extending undergraduate courses from three to four years from matriculation, at Newcastle a four-year course for the honours degree was instituted, the first three years being identical with those for the pass degree.⁽⁴⁹⁾

In the early 1890s there were thus only four institutions accepted as providing 'advanced' instruction. However, during the closing years of the nineteenth century another regional centre to lay the foundations for advanced academic qualifications was Cardiff, where the University College opened in 1894; four years later metallurgy 'was adopted by the

(47) SEXTON, A. Humboldt, op.cit., 99.

(48) MAXWELL, D., personal communication, 1980.

(49) SMYTHE, J.A., 'Armstrong College, Newcastle-upon-Tyne. University of Durham'. Contribution to Carpenter (1924), 61.

University of Wales as one of the final courses qualifying for the B.Sc. degree'. A student who completed this course in 1903 was later claimed to be 'the first graduate' in British metallurgical education,⁽⁵⁰⁾ although clearly G.P. Chaplin with his Durham degree of 1897 would seem to be equally worthy of this distinction. At Cardiff, besides the award of the B.Sc.(Wales), a College Diploma in metallurgy was available; metallurgical instruction was also given to students of mechanical engineering and mining.

In the first decade of the new century there were further substantial developments. The Mason College became part of the University of Birmingham in 1900, a chair of metallurgy being created two years later; in 1905 Sheffield University College, which had been formed in 1897 by fusion of the Technical School, Firth College, and other elements, became an independent university. In the following year a department of metallurgy was created in the University of Manchester, while at the same date the Manchester Municipal College of Technology, with its department of metallurgy, became a constituent college of the university.⁽⁵¹⁾ Thus, within the short space of half-a-dozen years, the number of institutions able to award degrees or equivalent diplomas in metallurgy increased by three. By 1910 the University of Leeds had added metallurgy to its list of subjects in which instruction was available, although in this case tuition came under the direction of the Livesey Professor of Coal Gas and Fuel Industries with Metallurgy, and fuel comprised a major portion of the course. A University Diploma in fuel and metallurgy could be bestowed on candidates who did not satisfy the requirements for the B.Sc. degree. Not until 1920 was a full-time lecturer in metallurgy appointed, and a professorship in the subject did not materialise until after 1950, although from 1933 there was a readership.⁽⁵²⁾

Another academic development in the opening decade of the present century was the establishment, in 1908, of a readership in metallurgy in the University of Cambridge where, for twenty years previously, research

(50) READ, A.A., 'University College, Cardiff. University of Wales'. Contribution to Carpenter (1924), 63.

(51) RHEAD, E.L., 'Municipal College of Technology, Manchester'. Contribution to Carpenter (1924), 67.

(52) O'NEILL, Hugh, op.cit., (1948), 25.

on some aspects of the subject had been carried out at Sidney Sussex College by two dedicated individuals, C.T. Heycock and F.H. Neville. Unlike most other university departments of metallurgy, the Cambridge endeavour began with post-graduate work. The prospects for research training and for obtaining the higher degrees of M.Sc. and Ph.D. proved so attractive that fresh accommodation was provided in 1912 and again in 1920, by which date there was said to be room for sixteen people.⁽⁵³⁾ Metallurgy was offered as a portion of the examinable topics for the B.A. degree thirty years after the readership had been created, in 1938; this was extended in 1942 to Part 1 of the Natural Science Tripos.⁽⁵⁴⁾ Meanwhile in 1932 the original readership was translated into a professorship. After 1940, and more particularly after 1950, the department of metallurgy in the University of Cambridge was to become one of the leading places for academic instruction in the subject.

Reverting to the years closer to the beginning of the century, in Glasgow the Royal Technical College, as the Glasgow and West of Scotland Technical College had been re-named, offered four-year courses in metallurgy for the college's Associateship and Diploma. In 1913 the college became affiliated to the university, and in 1915 the qualification of B.Sc. in applied chemistry was instituted for the benefit of students at both establishments.⁽⁵⁵⁾ Henceforward, students at the Royal Technical College could sit common examinations for both the Associateship and the B.Sc. The university's lectureship in metallurgical chemistry seems to have lapsed c.1930.

After the Glasgow consolidation around 1915, the next developments to take place were the introduction in 1920 of degree courses at the new University College of Swansea, and in Liverpool. At Swansea it was claimed that, by 1924, eighteen men had already graduated from the department of metallurgy:⁽⁵⁶⁾ such relatively-large numbers must have

(53) HEYCOCK, C.T., 'Goldsmiths' Metallurgical Laboratory, Cambridge'. Contribution to Carpenter (1924), 72.

(54) AUSTIN, G. Wesley, 'Department of metallurgy at the University of Cambridge'. Metal Treatment, (May 1954), 215.

(55) O'NEILL, Hugh, op.cit. (1948), 24.

(56) EDWARDS, C.A., 'Metallurgical department of the University College of Swansea'. Contribution to Carpenter (1924), 79.

been substantially aided by the post-war bulge. In Liverpool the University College had opened in 1882, and in its first year 'process metallurgy (including iron and steel) was taught in courses offered by the department of chemistry'. In subsequent years, metallurgical tuition continued to be given, and in 1907 it was extended to the faculty of engineering where a lecturer was made responsible for it.⁽⁵⁷⁾ At the University of Liverpool in 1920 a four-year course for B. Eng. in metallurgy was made available: besides this, metallurgy was offered as a special subject for final-year honours students of chemistry, and instruction in certain aspects was given to all candidates in dental surgery.⁽⁵⁸⁾

These two new metallurgical courses of 1920 brought to eleven the number of British academic departments which offered the subject at degree level. At the Royal School of Mines, students who satisfactorily completed the course did not obtain a degree: those who wished to add a B.Sc. degree to their Associateship had to enter for separate examinations of the University of London. Around 1920 about one-half of the students did this, but it was remarked by Sir Thomas Holland, rector of the Imperial College of which the Royal School of Mines was a part, that⁽⁵⁹⁾

'... the two examinations were not in step. The London degree was no stiffer, but the subjects were taken in a different order, and consequently students who attempted both qualifications were handicapping themselves by confusion ...'

By c.1925 arrangements had been arrived at whereby students sat only one set of examinations to qualify for both the school's Associateship and the London University's B.Sc. degree in the faculty of engineering. This latter qualification was also sought by a steady stream of 'external' candidates.

(57) KENNETT, S.J., A history of the department of metallurgy and materials science, University of Liverpool 1920-1970.
(Liverpool: the University, 1970), 1.

(58) BANNISTER, C.O., 'Metallurgy department, Liverpool University'.
Contribution to Carpenter (1924), 75.

(59) HOLLAND, Sir Thomas, in discussion of Carpenter (1924), 86.

Besides London, the University of Liverpool placed metallurgy within the faculty of engineering, but most other universities awarded metallurgy degrees in the faculty of science or applied science, while in the Municipal College of Technology in Manchester examinations led to Pass B.Sc. (Tech) in applied chemistry.⁽⁶⁰⁾ The other exception was the University of Sheffield where, from 1917, the subject was regarded as sufficiently important to stand in a faculty of its own, and the qualifications awarded were B.Met. and, for higher degrees, M.Met. and D.Met., as well as Ph.D.⁽⁶¹⁾ The first Sheffield Ph.D. in metallurgy was awarded in 1923.

The thirty-year period up to 1920 seems to have been the time of most intense activity in the starting of metallurgy courses associated with university departments: during the following thirty years, although there was considerable consolidation, the number of new developments in this field was relatively small. At Sheffield University in 1934 a new course was inaugurated for a degree in foundry work, the only one in Britain. At Cambridge, as already remarked, examinations in metallurgy for parts of the Tripos were instituted in 1938. In the University of Oxford, research by a lone worker, Dr. W. Hume-Rothery, was conducted within the chemistry school from 1926, and lectures were given by him to the school, particularly after 1938; metallography 'was officially recognised as a supplementary subject in the final honour school of natural science' in 1949, while a few years later metallurgy was to be included in final-year examinations, so establishing the subject in the university.⁽⁶²⁾ At the University of Nottingham a lecturer in metallurgy was appointed in 1949 and a separate department headed by a professor was to be formed during the 1950s. These developments took place nearly three-quarters of a century after the first introduction of academic staff to teach the subject, for in 1881 Frank Clowes was appointed 'professor of chemistry and metallurgy' at the University College, a post he retained until 1897,

(60) THOMPSON, F.C., 'Metallurgical education in the Victoria University of Manchester'. Contribution to Carpenter (1924), 65.

(61) Carpenter (1924), 48.

(62) ANON., 'Metallurgy at Oxford'. The Metallurgist, vol. 1., no.4 (July 1960), 138.

although for the period 1887-1890 he was also the college's first principal.⁽⁶³⁾

In Birmingham, during the second half of the 1940s, the University's department of metallurgy was divided into two streams: industrial metallurgy, and physical and theoretical metallurgy, with a total of four professors between them. The institution was thus equipped to enter the second half of the twentieth century with two alternative courses, intended to cater for a wider range of students' needs, and to greater depth, than would otherwise have been possible.

The organised classes of instruction reviewed above represent only one way, although certainly the most important, by which metallurgical information might be acquired by individuals. Contributions to the dissemination of information also came from the meetings of appropriate groups: besides the aural communications taking place at the meetings, and the valuable personal contacts made, many groups sponsored the production of written records which formed useful sources. Two bodies germane to metallurgists had been started before 1851, the Institution of Civil Engineers and the Institution of Mechanical Engineers. Several relevant societies came into being, and developed, during the period 1851 - 1950. Only one or two years after 1851 there was formed in Newcastle-upon-Tyne the North of England Institute of Mining Engineers, and subsequently the example of this body was followed in other parts, so that by 1890 there were in existence societies involving mining, iron-making and engineering in the various localities in which these activities were important. On a national basis, the Iron and Steel Institute was formed in 1869, and for the next 105 years it played an important part in furthering international knowledge of technical aspects of the industry. In 1892 came the start of the Institution of Mining and Metallurgy while, reflecting the growing use of metals and the extension of alloys, in 1908 there was founded another national society, the

(63) WOOD, A.C., A history of the University College Nottingham 1881-1948. (Oxford: B.H. Blackwell, 1953), 171;174.

Institute of Metals which, by the end of the 1940s, had local sections operating in several regions, such as that around Birmingham. In Manchester a metallurgical society was founded in 1919,⁽⁶⁴⁾ and in Sheffield there was a local metallurgical and engineering society. A national Institute of British Foundrymen was formed in 1904 to cater for the interests of that branch of industry. In 1946 there came into existence the Institution of Metallurgists, a professional body which tried to enhance the interests of its members and paid particular attention to standards, seeking to improve metallurgical 'education'. One other group which, despite its brief life, deserves mention is the Inter-Varsity Conference of Metallurgical Students: this was active from c.1925 to 1930.

In response to two main forces, market demand and increasing knowledge, a growing volume of metallurgical literature was created. Contributions to this body came from three directions: from the printed Proceedings and other publications of societies; from commercial periodical publications; and from textbooks. As far as the periodical publications of societies are concerned, the Minutes of Proceedings of the Institution of Civil Engineers and the Proceedings of the Institution of Mechanical Engineers both sporadically provided material of metallurgical significance. For example, there were accounts of the dressing of ores in Cornwall, of the treatment of complex ores and condensation of lead fumes, of the construction of Bessemer steel-making converters, and of the Scottish works of the British Aluminium Company. In addition, in the years after 1891 the Institution of Mechanical Engineers was responsible for producing a series of volumes dealing with research into alloys. Similarly, the Proceedings of the Society of Chemical Industry, entitled Chemistry and Industry, contained information on metallurgical plant and processes. Specifically in the metallurgical field, the Journal of the Iron and Steel Institute was published regularly from 1869 to 1974, while that of the Institute of Metals appeared from 1909; the first issue of the Institution of Metallurgists' Bulletin was produced in 1946.

(64) ANON., 'The Manchester Metallurgical Society's golden jubilee'. Metals Materials, (Dec. 1969), 469-470.

The products of learned societies and technical gatherings were supplemented by commercial publications, such as The Iron and Coal Trades Review, started in 1869, and still appearing, albeit under a different title, in 1982. In similar fashion, although not devoted exclusively to metallurgical endeavours, several other periodicals contained significant proportions of metallurgical items, for instance: The Mining Journal, published in London throughout the period; Engineering, started in 1866, and The Engineer, begun ten years before; The Mining and Smelting Magazine, which unfortunately had only a brief life of less than three years in the 1860s; and Iron, a continuation from 1873 of The Mechanics' Magazine, which had first appeared in 1823. For fifteen years between 1925 and 1941 The Engineer published a monthly supplement entitled The Metallurgist. From the western side of the Atlantic Ocean originated commercial periodicals such as Engineering and Mining Journal and, later, Metal Progress. Among the titles of periodicals which dealt specifically with metallurgy were: The Metallographist, produced in Boston Massachusetts from 1898 until 1906, and distinctive in being concerned with the structures of metals and alloys rather than with their production details; The Metal Industry, founded in 1909 and published in London; Metallurgia, originating in Manchester in 1929; and Metal Treatment, which began publication in 1935.

Printed textbooks were produced, and by the early years of the present century provided comprehensive accounts of the methods used for extracting the various metals from their ores, and the equipment involved in the treatments. Thus, the decade of the 1860s saw the publication of a number of relevant books: J.H. Pepper's Playbook of metals appeared in 1861,⁽⁶⁵⁾ as did The useful metals and their alloys.⁽⁶⁶⁾ Within the next two or three years came Dr. John Percy's several volumes which made up an encyclopedic account of Metallurgy ...,⁽⁶⁷⁾ and at much the same time

(65) PEPPER, J.H., The playbook of metals.
(London: Routledge, Warne, 1861).

(66) SCOFFERN, J. TRURAN, W. and others, The useful metals and their alloys. (London: Houlston and Wright, 1861).

(67) PERCY, John, Metallurgy ... fuel, fire-clays, copper
(London: John Murray, 1861);
Metallurgy ... iron and steel
(London: John Murray, 1864).

George Makin's A manual of metallurgy.⁽⁶⁸⁾ Before 1870 there were published The mining and metallurgy of gold and silver,⁽⁶⁹⁾ A treatise on the metallurgy of iron ...,⁽⁷⁰⁾ and Manufacture of iron and steel.⁽⁷¹⁾ These were shortly followed by Metals: their properties and treatment,⁽⁷²⁾ A practical treatise on the art of extracting metals from their ores,⁽⁷³⁾ another Manual of metallurgy by a different author,⁽⁷⁴⁾ and I.L. Bell's Chemical phenomena of iron smelting:⁽⁷⁵⁾ this last book had the rare distinction of being written by a practising and successful ironmaster.

Around 1890 there were issued: An introduction to the study of metallurgy, by W.C. Roberts-Austen, professor at the Royal School of Mines in London as successor to Dr. Percy,⁽⁷⁶⁾ and the Beringer brothers' Text-book of assaying ...:⁽⁷⁷⁾ while from the USA came Modern copper smelting,⁽⁷⁸⁾ and The metallurgy of steel, by H.M. Howe.⁽⁷⁹⁾

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- (68) MAKINS, George H., A manual of metallurgy.
(London, 1862, 1st edn.)
- (69) PHILLIPS, John A., The mining and metallurgy of gold and silver.
(London, 1867)
- (70) BAUERMAN, H., A treatise on the metallurgy of iron
(London: Virtue, 1868).
- (71) KOHN, F., Manufacture of iron and steel.
(Glasgow and London: Mackenzie, 1869).
- (72) BLOXAM, Charles Loudon, Metals: their properties and treatment.
(London: Longmans, 1870). (Text-books of science).
- (73) PHILLIPS, J. Arthur and BAUERMAN, H., A practical treatise on the art of extracting metals from their ores.
(London: Charles Griffin, c.1874, 1st edn.)
- (74) GREENWOOD, W.H., A manual of metallurgy, 2 vols.
(London and Glasgow: William Collins, 1873, 1st edn.).
- (75) BELL, Isaac Lowthian, Chemical phenomena of iron smelting.
(London: Routledge, 1872).
- (76) ROBERTS-AUSTEN, W.C., An introduction to the study of metallurgy.
(London: Charles Griffin, 1890-91, 1st edn.)
- (77) BERINGER, C. and BERINGER, John Jacob, A text-book of assaying, for the use of those connected with mines
(London: Charles Griffin, 1889).
- (78) PETERS, Edward D., Modern copper smelting.
(New York and London: The Scientific Publ.Co., 1887, 1st edn.)
- (79) HOWE, Henry Marion, The metallurgy of steel.
(New York and London: The Scientific Publ.Co., 1890).

In the early years of the new century the scope was widened: there appeared a three-volume work on Metallurgical calculations,⁽⁸⁰⁾ as well as more books that confined themselves to one or two metals, such as The metallurgy of lead and silver,⁽⁸¹⁾ Production and properties of zinc,⁽⁸²⁾ Hydrometallurgy of silver,⁽⁸³⁾ Metallurgy of steel,⁽⁸⁴⁾ and The metallurgy of gold.⁽⁸⁵⁾

Five of the titles noted above were published in the USA, and from about 1890 that country became an important source of relevant books written in English. Just before the turn of the century, a major Continental text appeared in an English version: this was Dr. Carl Schnabel's Handbook of metallurgy, which was translated by Henry Louis, professor of mining and lecturer on metallurgy at Armstrong College, Newcastle-upon-Tyne.⁽⁸⁶⁾ Robert-Austen's successor as professor of metallurgy at the Royal School of Mines, William Gowland, produced a book, The metallurgy of the non-ferrous metals, in 1914,⁽⁸⁷⁾ while his successor in turn,

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- (80) RICHARDS, Joseph, W., Metallurgical calculations, 3 parts.
(New York and London: McGraw-Hill Book Co., 1st edn.
1906 (pt.1), 1907 (pt.2), 1908 (pt.3)).
- (81) COLLINS, Henry Francis, The metallurgy of lead and silver, 2 vols.
(London: Charles Griffin, 1899).
- (82) INGALLS, Walter Renton, Production and properties of zinc.
(New York and London: The Engineering and Mining Journal,
1st edn. 1902).
- (83) HOFMANN, Ottakar, Hydrometallurgy of silver
(New York and London: Hill Publ.Co., 1907).
- (84) HARBORD, Frank W., The metallurgy of steel ... with a section on the mechanical treatment of steel by J.W. Hall
(London: Charles Griffin, 1st edn. 1904).
- (85) ROSE, T. Kirke, The metallurgy of gold.
(London: Charles Griffin, 1st edn. c.1912).
- (86) SCHNABEL, Carl, (transl. by) LOUIS, H., Handbook of metallurgy,
2 vols. (London: Macmillan & Co., 1st edn. 1898).
- (87) GOWLAND, William, The metallurgy of the non-ferrous metals.
(London: Charles Griffin, 1st edn. 1914).

H.C.H. Carpenter, was co-author of a massive two-volume work simply entitled Metals, which appeared in 1939.⁽⁸⁸⁾ The professor of mining at the school wrote a Text-book of ore dressing,⁽⁸⁹⁾ which was published in 1923 and competed with the earlier American work by R.H. Richards.⁽⁹⁰⁾ Besides being responsible for The Metallurgy of iron and steel ...,⁽⁹¹⁾ Thomas Turner, professor of metallurgy in the University of Birmingham, also produced a book on Practical metallurgy⁽⁹²⁾ An early example of collaborative writing came from South Africa in 1912 in the form of a Text-book of Rand metallurgical practice,⁽⁹³⁾ while fourteen years later a joint effort in the USA resulted in the Handbook of non-ferrous metallurgy.⁽⁹⁴⁾

During the twentieth century there was, on the whole, a marked decline in the production of new books devoted to details of the extraction of metals from their ores; instead there began to appear

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- (88) CARPENTER, H.C.H., and ROBERTSON, J.M., Metals, 2 vols.
(London: Oxford Univ.Press, 1939).
- (89) TRUSCOTT, S.J., A text-book of ore dressing.
(London: Macmillan, 1923)
- (90) RICHARDS, Robert Hallowell, Ore dressing, 4 vols.
(New York and London: Engineering and Mining Journal, 1909);
(with others), A textbook of ore dressing.
(New York and London: McGraw-Hill 1909).
- (91) TURNER, Thomas, The metallurgy of iron and steel ..., 2 vols.
(London: Charles Griffin, 1st edn. 1895, 5th edn. 1918).
- (92) TURNER, Thomas, Practical metallurgy: an introductory course for general students ... with illustrations.
(London: Charles Griffin, 1st edn. 1908, 2nd edn. 1919).
- (93) STOKES, Ralph and others, A text-book of Rand metallurgical practice, 2 vols.
(London: Charles Griffin, 1st edn. 1912).
- (94) LIDDELL, Donald M. (editor in chief), Handbook of nonferrous metallurgy, 2 vols.
(New York and London: McGraw-Hill, 1st edn. 1926).

books which were concerned with the properties and behaviour of metals. An early example in this category is C.H. Desch's Metallography ..., first published in 1910, and reaching its 6th edition by 1944.⁽⁹⁵⁾ During the 1920s this was joined by a laboratory handbook, Practical microscopical metallography,⁽⁹⁶⁾ produced by research staff at the Royal Arsenal in Woolwich, while Carpenter and Robertson's Metals continued this trend. Even more remote from metal production were the books of Dr. W. Hume-Rothery, such as The metallic state of 1931,⁽⁹⁷⁾ The structure of metals and alloys of 1936,⁽⁹⁸⁾ and Atomic theory for students of metallurgy, published in 1947;⁽⁹⁹⁾ these were indicative of the direction that academic metallurgical studies were to take in the 1950s and 1960s.

Many of the books produced during the hundred-year period, and especially those concerned with metals' production, were entirely descriptive, although Roberts-Austen's work An introduction to the study of metallurgy adopted an analytical approach that has a curiously-modern ring to it. Finally, it is appropriate to mention one twentieth-century book which successfully reached a comparatively-popular market: this

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- (95) DESCH, C.H., Metallography (London: Longmans, Green, 1st edn. 1910). (Text-books of physical chemistry).
- (96) GREAVES, R.H. and WRIGHTON, H., Practical microscopical metallography. (London: Chapman and Hall, 1st edn. 1924).
- (97) HUME-ROTHERY, William, The metallic state. Electrical properties and theories. (Oxford: Clarendon Press, 1931).
- (98) HUME-ROTHERY, William, The structure of metals and alloys. (London: Institute of Metals, 1936).
(Inst. of Metals monograph and report series, no.1).
- (99) HUME-ROTHERY, William, Atomic theory for students of metallurgy. (London: Institute of Metals, 1947).
(Inst. of Metals monograph and report series, no.2).

was Metals in the service of man, by Arthur Street and William Alexander, which was first published by Penguin Books in 1944, and was to run into many editions.⁽¹⁰⁰⁾

From all of the above it may be concluded that means for instruction in metallurgy grew many-fold during the hundred years 1851 - 1950. Organised classes multiplied: in the 1850s there were few opportunities for formal tuition in technical subjects of any kind, but by 1950 metallurgical instruction was available at more than twenty technical colleges situated in different parts of the country and the examination goals were the ONC, HNC, and City and Guilds' qualifications. As many as 6000 students of the subject at some level were enrolled in more than 350 classes, while others received instruction during courses in engineering, foundry work and chemistry. Compared with the single 'advanced' day-time class offered at the Government School of Mines in 1851, and the average of about one student a year who successfully completed the course between 1851 and 1868,⁽¹⁰¹⁾ by the end of the 1940s there were some 200 students reading for B.Sc. degree in metallurgy or their equivalent; ten British universities bestowed such degrees, and full-time undergraduate courses leading to these awards were provided at thirteen or fourteen colleges, with part-time instruction given at another half dozen. At the same time, during the hundred-year period the opportunities for obtaining metallurgical information from technical meetings and from the printed word increased greatly.

Despite the extent of these advances it could be argued that the provisions for metallurgical instruction in 1950 were still inadequate. During the next fifteen years of the twentieth century opportunities were to continue to increase.

(100) STREET, Arthur and ALEXANDER, William, Metals in the service of man. (Harmondsworth, Mddx.: Penguin Books, 1st edn.1944). (Pelican Book A125).

(101) YOUNG, J., 'On the education of the mining engineer'. Trans.N.England Inst.Min.Mech.Engrs., vol. 21 (1871-72),28-29.

CHAPTER 4GOVERNMENTAL INFLUENCE THROUGH ITS EDUCATION OFFICE

At the opening of the century 1851 - 1950 the British Government's administrative machinery for education was the Privy Council Committee on Education which had been created in 1839 to regulate elementary schooling. In the period from 1856 to 1899 this function was performed by the Education Department. Between 1899 and 1945 involvement was continued through the Board of Education, while re-arrangement once more led in 1945 to a Department of Education, this time headed by a minister for education.

Governmental financial participation in education had first materialised in 1833, when grants of £20 000 were made to voluntary societies to help their efforts at elementary schooling.⁽¹⁾ At that time there was no branch of Government apparatus charged solely with the task of promoting education. Two years later, in 1835, a Select Committee under the chairmanship of William Ewart, MP, had been charged with considering how best a knowledge of the arts and the principles of design might be fostered for industrial purposes. Resulting from a recommendation by this committee the first 'school of design' was formed in 1836 with the help of £1500 from Government, opening in rooms in Somerset House, London, the following year, and representing the earliest instance of State aid for education other than elementary. In 1840 the first school inspectors were appointed.⁽²⁾ In the same year the foundation and maintenance of further schools of design was helped by the establishment of a Department of Practical Art, for which Government granted £10 000 a year. By 1851, the sum allocated for this

(1) ARGLES, Michael, South Kensington to Robbins an account of English technical and scientific education since 1851. (London: Longmans, 1964), 5.
Hereafter referred to as 'ARGLES (1964)'.

(2) ARGLES (1964), 6.

purpose had increased to £15 000,⁽³⁾ and schools were in existence in more than twenty provincial towns; at Sheffield, for instance, one had been opened in 1843.⁽⁴⁾ However, the Department of Practical Art was controlled by the Board of Trade, and was therefore completely independent of the Committee on Education. In 1851, the annual parliamentary grant for education had increased to £164 000,⁽⁵⁾ and in the same year the Committee of Council on Education gave its first aid for evening classes devoted to adult elementary instruction.⁽⁶⁾

The seminal year 1851, marking the beginning of the second half of the nineteenth century, also saw, on 6 November, the official opening in London of the Government School of Mines and of Science applied to the Arts. Despite its significance as the first institution for 'higher education' into which Government funds were injected, the school at its inception was not controlled by the Committee on Education but, instead, had come into being as part of the Office of Woods and Forests. The foundation of the school is therefore not considered in any detail here, but will be described in the subsequent chapter devoted to Governmental influences other than those effected directly through the medium of the education office. Suffice it to say that in 1854 the School of Mines, together with the other portions of the Geological Survey and Museum, found themselves transferred to the newly-formed Department of Science and Art.⁽⁷⁾ In the field of technical instruction the Science and Art Department was to be the chief vehicle for Government aid throughout the second half of the nineteenth century, with significant influence upon the development of metallurgical classes. Resulting from an inquiry in 1852, the department was established in March 1853 as an extension of the Department of Art founded thirteen years before. Like the School of Mines, the

(3) MILLIS, C.T., Technical education its development and aims.
(London: Edward Arnold, 1925), 26.

(4) ARGLES, (1964), 8.

(5) ARGLES (1964), 6; quoting BARTLEY, G.C.T., The schools for the people, (1871), 49.

(6) ARGLES (1964), 9.

(7) BAILEY, Sir Edward, Geological Survey of Great Britain.
(London: Murby, 1952), 49.

Science and Art Department was not at first under the Committee on Education, being instead the responsibility of the Board of Trade. However, within four years it was transferred in its turn to the new Department of Education. The objects of the Science and Art Department were 'to extend a system of encouragement to local institutions for Practical Science, similar to that already commenced in the Department of Art ... on an enlarged scale'.⁽⁸⁾ The institutions which the 1852 Board of Trade inquiry expected would come under the department's control are listed in Table 4.1, together with their estimated yearly costs which amounted to just under £40 000.

One of the commissioners for the Exhibition of 1851, Henry Cole (b.1808-d.1882), had been made secretary of the Department of Practical Art in 1852, and in the following year he became the senior of the two joint secretaries of the new enlarged department, in charge of art, while the other joint secretary, responsible for science and with a salary of £1000, was another 1851 commissioner, Lyon Playfair (b.1818-d.1898).⁽⁹⁾

Shortly afterwards, no less than twelve science schools were opened as joint ventures of the Science and Art Department and interested bodies in the localities concerned, the schools being situated at 'Aberdeen, Birmingham, Bristol, Barking, Leeds, Newcastle-upon-Tyne, Poplar (a trade school in connexion with the navigation school), Stoke-on-Trent, St. Thomas' Charterhouse (in London), Truro, Wigan and Wandsworth.' However, by 1859 'with the exception of the navigation schools', only at four places were science classes under the department still active, with a total of 395 pupils in attendance: Aberdeen, Birmingham, Bristol and Wigan.⁽¹⁰⁾ During the period from 1853 to 1859 financial aid to science classes amounted to only £898.⁽¹¹⁾

(8) REEKS, Margaret, Register of the associates and old students ... and history of the Royal School of Mines.
(London: RSM Association, 2nd edn. 1920), 66.

(9) REEKS, Margaret, op.cit., 66ff.

(10) MILLIS, C.T., op.cit., 27.

(11) ARGLES (1964), 19; quoting BARTLEY, G.C.T., The Schools for the people. (1871), 128.

Table 4.1. Institutions proposed to be put under control
of the Science and Art Department, 1853

I n s t i t u t i o n	Estimated Annual Cost		
	£	s.	d.
The Government School of Mines and of Science Applied to the Arts	800	0	0
The Museum of Practical Geology	5 272	0	0
The Geology Survey	5 500	0	0
The Museum of Irish Industry	3 346	6	0
The Royal Dublin Society	6 340	15	0
The Department of Practical Art, including the Provincial Schools of Design	17 920	0	0
	39 181	1	0
(i.e. £39 181.05)			

REEKS, Margaret, Register of the associates and old students ...
and history of the Royal School of Mines.
(London: RSM Association, 2nd edn. 1920), 66.

By 1859 there had been two further significant developments: a State education department had been formed, and the decision had been made to establish a system of grants in aid of Science and Art Classes for the whole country. The Education Department was constituted by Order in Council in 1856, under the lord president of the privy council (a member of the House of Lords) and the vice-president (in the Commons) of the Committee of Council on Education. To this new department in 1857 the Science and Art Department was transferred from the Board of Trade. Henry Cole became permanent secretary of the Education Department. In practice the department's work soon came to be regarded as comprising two components, the main department in Whitehall which was concerned with elementary education, and the Science and Art Department in South Kensington which

continued its former responsibilities for instruction in the topics implicit in its title.⁽¹²⁾

In 1859 J.F.D. Donnelly (b.1834-d.1902) was appointed to the Science and Art Department as inspector for science, and subsequently he exerted considerable influence on the national development of artistic and scientific instruction. Fifteen years after his first appointment he was given the title of director of science, becoming controller of the Royal School of Mines, the Royal College of Chemistry, the Royal College of Art, and the Royal College of Science for Ireland.⁽¹³⁾ After 1880 Donnelly became secretary of the Science and Art Department.

The year 1859 also marked the beginning of the era of grants to encourage classes in certain aspects of science and art; with the period is linked the idea of 'payment on results' of examination which, especially in more recent years, has been the object of adverse criticism. It was decided to 'assist the industrial classes ... in supplying themselves with instruction in the rudiments of geometry, mechanical drawing, building construction, physics, chemistry, and natural history'.⁽¹⁴⁾ To this end the Science and Art Department organised an examination system from 1860 onwards, and augmented the salaries of approved teachers preparing classes of candidates by paying them sums of £1 or more, depending upon the level, for each student who successfully passed one of the examinations. Every subject was subdivided into three stages: elementary, advanced, and honours. The sums of money distributed on this basis increased with the years: £2666 in 1862, £25 000 in 1872, £73 000 in 1886, and £158 000 in 1896.⁽¹⁵⁾ Similarly, the numbers under instruction in the various classes grew: from a total of 500 in 1860, to 36 000 in 1872;⁽¹⁶⁾ but not all were necessarily examination candidates.

(12) MILLIS, C.T., op.cit., 27.

(13) REEKS, Margaret, op.cit., 127.

(14) ARGLES (1964), 20; quoting SCIENCE AND ART DEPARTMENT, Sixth report, (1859). 'Payment on results' was the phrase used in some, at least, of the official publications of the Science and Art Department, e.g. the Extract from the science directory revised to June 1885 ..., (London, 1885), iii; 3; 17. Similarly, it was used by C.T. MILLIS, writing in 1925 after a lifetime spent in further education, e.g. op.cit., 27.

(15) MILLIS, C.T., loc.cit.

(16) BECKER, Bernard, Scientific London. (London: H.S. King, 1874), 156; MILLIS, C.T., op.cit., 27, gives similar figures.

For example, one writer states that in May 1860, 104 candidates sat papers, while in 1875 the number was just under 28 000.⁽¹⁷⁾ Problems of detail apart, the general trends are unequivocal.

The estimates of expenditure for the Science and Art Department in the financial year April 1874 to March 1875, excluding the vote for the Geological Survey, called for £ $\frac{1}{4}$ million. Out of this sum, the Royal College of Science in Dublin was allocated £6883, the Royal School of Mines and Geological Museum in London £8998, and the schools of Science and Art £120 110. Of this last item, £40 500 was required for payments to teachers of science, with £17 500 for 'artisans attending night classes', £7800 for prizes and £2350 for scholarships.⁽¹⁸⁾

Gold medallists in the examinations were granted the privilege of attending the lecture courses and examinations at the Royal School of Mines without payment, and in addition the Science and Art Department had power to award scholarships and exhibitions to help the best candidates to study at the Royal School of Mines for up to three years with a view to obtaining the Associateship. Beginning in 1869, by means of short courses held at the school, encouragement was also given to science teachers, who received aid towards travelling and subsistence while attending them.

Another form of instruction was provided in the Museum of Practical Geology, which was closely associated with the Royal School of Mines. The museum remained open until 10 o'clock on Monday and Saturday evenings, and contained displays illustrating such metallurgical topics as the occurrence and forms of ores, their treatment to produce metals, and the subsequent manufacture of useful articles of commerce. Thus, there was exhibited a vein of gold-bearing quartz from California, and a sequence showing the extraction of copper from its ore and the forming of an elegant copper vase from a disk of the metal. On iron and steel there were displayed a wide variety of ores, specimens of pig iron from works

(17) MUSGRAVE, P.W., 'Metallurgy and the Department of Science and Art, 1870-1900'. In MUSGRAVE, P.W. (ed.), Sociology, history and education a reader, (London: Methuen, 1970), 265; 268.

(18) BECKER, Bernard, op.cit., 157, 158.

in several British localities, models of blast furnaces and blowing engines, and numerous examples of products such as screws, springs, swords and ornamental castings. There was 'a model of a Sheffield steel manufactory, including furnaces, rolling mills, and a forge' and, by 1874, another model which represented 'the whole apparatus employed in making Bessemer steel': one enthusiastic observer at that time commented that 'this model alone would repay a visit to the museum'.⁽¹⁹⁾

The lecture theatre of the Museum of Practical Geology and the Royal School of Mines, situated between Piccadilly and Jermyn Street, was the scene of the Monday evening lectures for artisans which were delivered throughout almost the whole of the second half of the nineteenth century. The lecture theatre apparently had space for 600, and on many occasions it was filled. The admission fee to attend a course of six lectures was 6d. (£0.02½) and, at any rate in the 1870s, each member of the school's staff delivered a course in alternate years. For example, Dr. John Percy, in charge of metallurgy, gave a course on 'metals' in the 1873-74 session, while there were two other courses delivered by Professor Guthrie on 'heat' and Professor Huxley on 'natural history'.⁽²⁰⁾ By all accounts, during the third quarter of the nineteenth century, these 'popular' evening lectures for artisans were one of the most successful of the limited attempts made to provide general scientific instruction. They were favourably compared with the evening classes offered by King's College, which were considerably more costly.

By 1862 metallurgy was included among the subjects for which grants were paid, and from then until 1889, this was the sole source of public money for aiding part-time metallurgical instruction. According to P.W. Musgrave, numbers sitting the examinations in this subject were small, particularly in the earlier years: in Table 4.2 are quoted the numbers of candidates in selected years between 1870 and 1900 together with the numbers of scripts in two earlier years.

(19) BECKER, Bernard, op.cit., 256-257.

(20) BECKER, Bernard, op.cit., 184-185.

Table 4.2. Numbers sitting Science and Art Department
Examinations in metallurgy, 1870 - 1900.

Year	Total number Examined, all subjects	M e t a l l u r g y		Metallurgy as propor- tion of total, per cent.
		Theory (subject 19)	Practical (subject 19p)	
		(first year 1863)	(first year 1883)	
1863	2 671 scripts	63	-	2.36
1866	5 466 "	62	-	1.13
1870	16 515 candidates	160	-	0.97
1875	27 985 "	173	-	0.62
1880	34 678 "	277	-	0.80
1885	48 497 "	351	126	0.98
1890	83 070 "	514	253	0.92
1895	108 193 "	534	391	0.85
1900	151 279 "	463	370	0.55

1863 figures: SCIENCE AND ART DEPARTMENT, Eleventh report of Science and Art Department (for year 1863), (HMSO, 1864), 16;
 1866 figures: SCIENCE AND ART DEPARTMENT, Fourteenth report ...;
 all other figures: MUSGRAVE, P.W. (ed.), Sociology, history and education a reader, (London: Methuen, 1970), 268.

Until after 1880, neither Middlesbrough nor Sheffield was included in the list of places which submitted examination scripts in metallurgy, but five years later each of the two towns provided thirty candidates in theoretical metallurgy and, in 1890, ten candidates. By 1895, however, while for Sheffield the number had risen to 85, for Middlesbrough it had fallen to nil. As far as the practical metallurgy examinations were concerned, Middlesbrough entered twenty candidates in 1885 against Sheffield's ten, while five years later both had ten, and five years

later again there were none.⁽²¹⁾ In his report on the examinations in 1886, Professor W.C. Roberts-Austen of the Royal School of Mines observed that⁽²²⁾

'The teaching of metallurgy, from the nature of the appliances, diagrams, and specimens required, must always be attended with difficulty and expense, and the number of candidates who present themselves will probably never be large, when compared with certain other subjects.'

In all subjects, the relatively-small numbers who entered for the practical courses were commented upon by critics of the system developed by the Science and Art Department.

Items shown at the Paris Exhibition in 1867 served to disturb the confidence of British manufacturers. Arising from this unpleasant experience, in the following year, just after Disraeli's minority Government had come to power, there was set up a Parliamentary select committee 'to inquire into the provisions for giving instruction in theoretical and applied science to the industrial classes'. The chairman of this committee was Bernhard Samuelson (b.1820-d.1905), a successful maker of agricultural machinery and a practising ironmaster with works in Cleveland. Sir Eric Ashby in 1958 commented that⁽²³⁾

'The report of this Committee is a turning-point in the history of technology in Britain, for it set technical education on the course that led to twentieth-century industrial Britain. ... It was a blueprint for the rest of the century. Indeed, it has required nearly three generations of committees and the challenge from the continent of two wars to persuade the British public to implement all these recommendations.'

(21) MUSGRAVE, P.W., op.cit., 270.

(22) ROBERTS-AUSTEN, W.C., 'Report in metallurgy', in ANON., Reports of the examiners on the results of the science examinations held in May and June 1886, (London: Eyre and Spottiswoode for HMSO, 1886), 32.

(23) ASHBY, Sir Eric, 'Education for an age of technology', chap. 32 in SINGER, C. and others (eds.) A history of technology volume 5: the late nineteenth century c.1850 to c.1900, (Oxford: Clarendon Press, 1958), 289; 291.

The committee concluded that the chief obstacles standing in the way of a technologically-informed and competitive nation were the wholly-inadequate provisions for both primary and secondary schooling, coupled with the lack of teachers of science.⁽²⁴⁾ The report implied State support for education, and it proposed that science should be introduced widely into the school curriculum at all levels. However, Disraeli's Conservative Government fell only a few weeks after the report had been presented to Parliament.

Two years afterwards, during W.E. Gladstone's first term as Liberal prime minister, there was appointed a Royal Commission on Scientific Instruction and the Advancement of Science; under the chairmanship of William Cavendish, Seventh Duke of Devonshire (b.1808-d.1891), and with B. Samuelson serving as a member, this was in being from 1870 to 1875. Of the eight reports issued by the Devonshire Commission, the first, among other things, was concerned with the future of the Royal School of Mines, while the second considered the wider classes in science supported by the Science and Art Department. The Duke of Devonshire, chairman of the inquiry, was himself interested in metals by virtue of his financial participation in railways and iron and steel at Barrow-in-Furness and elsewhere. In the year prior to the establishment of the commission he had been elected first president of the new Iron and Steel Institute. In their sixth report the commissioners included a much-quoted passage:⁽²⁵⁾

'The omission from a Liberal Education of a great branch of Intellectual Culture is of itself a matter for serious regret, and, considering the increasing importance of Science to the Material Interests of the Country, we cannot but regard its almost total exclusion from the training of the upper and middle classes as little short of a national Misfortune.'

Two of the actions recommended to Government in the Eighth report,

(24) ARGLES (1964), 26.

(25) ROYAL COMMISSION ON SCIENTIFIC INSTRUCTION, Sixth report, House of Commons, vol. XXVIII (1875), (C.1279), 10; quoted by MACLEOD, ROY M., 'Education: scientific and technical', in SUTHERLAND, G. and others (eds.), Education government and society in nineteenth-century Britain, (Dublin: Irish Univ. Press, 1977), 209.

issued in 1875, were creation of a ministry for science and education, and a national laboratory for technical purposes and physics.⁽²⁶⁾ Resulting from the commission's reports, the work of the Royal School of Mines and the associated Royal College of Chemistry, which had been absorbed in the 1850s, became broadened, with the primary emphasis shifted to training science teachers. Accompanying this change of aims, within the institution there was a corresponding decline in the relative importance of metallurgical instruction. In the unsympathetic circumstances it is remarkable that 'metallurgy' as a distinct subject for study managed to survive into the opening decade of the present century and to the re-organisation of the relevant teaching in South Kensington into the Imperial College of Science and Technology.

Of greater significance for present purposes was another Royal Commission, this time on technical instruction, which heard evidence in the years 1882 and 1883 and reported its findings in 1882-1884. As has been pointed out by Michael Argles, during the three-year period in which this particular Royal Commission was investigating, there were nineteen commissions 'in existence at one time or another' so that, 'to the Victorians it was just one of many'.⁽²⁷⁾ Argles has also argued that because the commission's members were all converts and in the nature of 'experts', it was a 'free-lance enquiry by a small pressure-group',⁽²⁸⁾ and it was therefore hardly impartial. The commission's reports made a strong case for greater Government involvement in the provision of instruction in science and technology, and laid particular stress on the need to train foremen and those others who would occupy commanding positions: 'your Commissioners believe that no portion of the national expenditure on education is of greater importance than that employed in the scientific culture of the leaders of industry'.⁽²⁹⁾

(26) MACLEOD, Roy M., 'Education: scientific and technical', in SUTHERLAND, G. and others (eds.), Education government and society in nineteenth-century Britain, (Dublin: Irish Univ. Press, 1977), 210. Hereafter referred to as 'MACLEOD (1977)'.

(27) ARGLES, M., 'The Royal Commission on technical instruction, 1881-4, its inception and composition'. Vocat. Aspect, vol. 11 (Autumn 1959), 97.

(28) ARGLES, M., op.cit., 98

(29) ROYAL COMMISSION ON SCIENTIFIC INSTRUCTION, Fourth report, House of Commons vol. XXII (1874), (C.884), ; quoted by MACLURE, J. Stuart, Educational documents England and Wales 1816 to the present day, (London: Methuen, 1973 edn.), 126.

While the work done by the Science and Art Department was acknowledged to be of value, several witnesses criticised the remoteness of the links between actual industries and the subjects sponsored. The recurrent

theme was of unfavourable comparisons between the conditions for education in Britain and those abroad.

In the fourteen months 'between July 1885 and August 1886 there were no less than three successive governments',⁽³⁰⁾ and consequently little immediate action was taken upon the commission's recommendations. However, following the creation in 1888 of new local authorities, the county councils and county borough councils, there was passed an Act of great significance. This, the Technical Instruction Act of 1889, empowered local authorities to raise penny rates (i.e. about £0.004) to produce funds for classes in technical subjects and to subsidise science in secondary schools. This legislation opened up possibilities for beginning classes on a wide scale under the responsibility of the local authorities, responsibility for elementary education remaining with the school boards which resulted from the Act of 1870.

In 1891 an extension of the 1889 Act gave local authorities power to provide scholarships to help students with fees and expenses at classes whose curricula had been approved by the Department of Science and Art. Stemming from the Local Taxation (Customs and Excise) Act of 1890 another and, for a number of years considerably larger, source of public funds soon became available in the shape of 'residue' grants, either to relieve the local rates or to help technical education. In 1892-93 funds from this latter source, the so-called 'whisky money', used by local authorities for the purpose of technical education, amounted to £472 560, while only £12 762 was raised by means of the penny rate. Seven years later, at the turn of the century, the corresponding figures were £836 847 and £106 209.⁽³¹⁾ Some authorities reacted more readily than others to the opportunity for raising local sums for technical education: however, by 1898 all the counties and county boroughs in England were making some use of the power,

(30) MACLEOD (1977), 213.

(31) MACLEOD (1977), 215; also ARGLES (1964), 35, quoting BALFOUR, Graham, The educational systems of Great Britain and Ireland. (Oxford: the Clarendon Press, 2nd edn. 1903), 167.

and out of £807 000 available, £740 000 was spent on education.⁽³²⁾ At the end of 1899 there were 49 English counties and 61 county boroughs, making a total of 110 councils eligible to provide technical instruction. Ninety-four of these councils, 85 per cent., were said to be applying the whole of the residue grants to technical education, while only twenty two, or twenty per cent., made grants from the rates. In Wales and Monmouthshire the proportion was much higher, with all sixteen councils applying the whole of the residue to 'intermediate and technical' education, and thirteen of the sixteen, equivalent to 81 per cent., making grants from the rates.⁽³³⁾

In the substantial development of classes that occurred, metallurgy occupied only a minor place compared with subjects such as chemistry and mining. While several county councils appointed lecturers in mining for their colliery districts, only one appointed a teacher of metallurgy: this was North Staffordshire where, during the second half of the 1890s Thomas Turner, ARSM, held this position. In 1902 he left on his appointment as professor of metallurgy in the newly-chartered University of Birmingham.

The period 1889 - 1899 was described in a Board of Education report of the 1920s as most fruitful for the development of nation-wide provisions for technical instruction, the most characteristic feature being 'the progress made in the matter of acquiring, improving, building and equipping premises for science, art and technology.'⁽³⁴⁾

In the classes sponsored by the Science and Art Department payment on attendance became the rule in 1897, although payments continued to be added for examination successes at advanced levels. Until 1897 the department remained prepared to grant sums of up to £500 towards the equipping of new premises for its science courses.

Important in the long term were the Government measures taken to improve general school education. The Education Act of 1870 attempted to

(32), ARGLES (1964), 35.

(33) BOARD OF EDUCATION, Survey of technical and further education in England and Wales. (HMSO, 1927), 14.
Board of Education, educational pamphlets, no. 49.
The material appeared originally as part of the annual report of the Board of Education for 1924-25.
Hereafter referred to as 'Education Survey (1927)'.
(34) Education Survey (1927), 12.

make elementary education available to all children, although it was some years before there were sufficient school places to accommodate all those eligible. One argument used by Mr. W.E. Forster when introducing his Education Bill to the House of Commons was that if children were unable to read and write, they were not likely to obtain much benefit from technical instruction aimed at helping Britain compete with her industrial neighbours. In 1876 an amending Act declared that all parents had the duty of ensuring their children between the ages of five and fourteen received instruction in 'the three Rs': subsequent legislation was aimed at making sure all children received several years' full-time schooling, and in the 1890s all fees for elementary education were abolished. At the same time, during the 1890s, 'evening continuation schools' were fostered by the Department of Education, the grants for these being computed 'upon the hours of attendance instead of upon the attainment of individual pupils'.⁽³⁵⁾ The purpose of these 'schools' was to provide attractive programmes of elementary education for those who were at work during the day; to some extent, instruction in manual and technical subjects was available in these evening classes.

In 1895 was published the report of a commission which had considered 'what are the best methods of establishing a well-organised system of secondary education in England ...'. This, the Bryce Commission, recommended there should be a central authority for secondary education under a minister of education, and moreover that this should also be the central authority for elementary education. Under this authority would be discharged the functions which, until then, had been carried out by the Education Department, the Science and Art Department, and certain aspects of the work of the Charity Commission. Taking action on the Bryce Report in an effort to bring together and co-ordinate many of the efforts being made in the education field by the State, Lord Salisbury's Conservative Government created a unified central authority by the Act of 1899, the Board of Education. The changes were continued by Mr. A.J. Balfour, the Conservative successor to Lord Salisbury, who introduced in the House of Commons the Education Act of 1902. By this measure and the Regulations of the Board

(35) Education Survey (1927), 11.

of Education made in 1904, the reorganisation was substantially completed. Although the 'superintendence of matters relating to education' was vested in the Board of Education, much of the responsibility for implementing the schemes was placed in the hands of local education authorities, that is the county councils and county borough councils. In the field of 'higher education', expenditure by local education authorities was initially limited to a twopenny rate (about £0.008).⁽³⁶⁾

By the administrative reorganisation, the pattern of education in England and Wales was set in a mould that was to persist without significant change for another forty years. County secondary schools were provided, greater numbers of scholarships were introduced and, from 1913, junior technical schools giving full-time day education were established and promoted. In 1904 the range of evening-class subjects for which financial support could be obtained was widened, while in the following year 'grants were offered for courses designed to meet the technical requirements of the students by grouped "day technical classes" '.⁽³⁷⁾

As far as the new secondary education was concerned, however, unfortunately the pattern laid down by the Government followed the lines of the existing grammar schools, with technical and even scientific instruction accorded definite second-rate status. The name of Robert Morant is closely associated with the formulation of this policy, whose results are reflected in the attitudes that were to endure in Britain until long after 1950. More positively, regulations published in 1907 stipulated that one quarter of the places should be free in all grant-aided secondary schools, thereby increasing the opportunities for those of humble means. In 1911 the consultative committee of the Board of Education on examinations in secondary schools published its report, which resulted in the creation of the 'school certificate' examinations, first held in 1917. Metallurgy was included among the subjects for the certificates in one year, but one year only, 1931.⁽³⁸⁾

(36) MACLURE, J. Stuart, Education documents England and Wales 1816 to the present day. (London: Methuen, 1973 edn.), 149. Hereafter referred to as 'MACLURE (1973)'.

(37) Education Survey (1927), 18.

(38) MUSGRAVE, P.W., Technical change the labour force and education. (Oxford, etc.: Pergamon Press, 1967), 145; quoting Board of Education Report, (1931), 28.

During the war of 1914-18, there was set up a departmental committee on juvenile education to consider the post-war relationship with employment. In its final report, produced in 1917, the committee recommended that the school-leaving age for all be raised to fourteen, and that those who did not remain full-time students to the age of eighteen should attend part-time day-continuation classes. The former of these proposals was incorporated in the Education Act of 1918, the Fisher Act, but because of the poor national economic climate the idea of compulsory part-time continuation schools was abandoned, the exceptional town where such a school was put into effect being Rugby.⁽³⁹⁾

The examination system started in 1859 by the branch of the Education Department known as the Science and Art Department continued in use after 1901, although grants on examination results were ended in 1906. In 1911 the examinations at elementary standard were abandoned, ostensibly for the reasons that they led to the study of single subjects in isolation instead of the 'grouped courses' which had come into favour, and 'they no longer served any purpose that would not be as well served by local examinations'. Board of Education policy was then to encourage local schools to formulate for its approval schemes involving largely-internal assessment of courses requiring two or three years of study with class attendance on three nights weekly.⁽⁴⁰⁾ However, the response from district institutions was poor, even when, during the war of 1914-18, the examinations at advanced level were similarly withdrawn, so leaving many part-time students with no chance to obtain qualifying certificates.

To serve its ends, in 1920 the Board of Education requested that in England and Wales the lower-grade examination in iron-and-steel manufacture of the City and Guilds' Institute be dropped, to encourage local colleges to establish their own examinations. However, as P.W. Musgrave has pointed out, this attempt failed to stimulate alternatives, and in 1933 the lower-grade examinations were re-introduced. In any case, numbers entering for the examinations in the period were small; compared with 253 entries in 1902, there were only 61 in 1929.⁽⁴¹⁾

(39) MACLURE (1973), 171.

(40) Education Survey (1927), 21.

(41) MUSGRAVE, P.W., op.cit., 158.

In some technical subjects, however, the ideas of the Board of Education did yield useful results, for they led to the foundation of the national certificate schemes. The first such courses were negotiated between officials of the Board and those of the Institution of Mechanical Engineers, with examinations taking place in 1922. Similarly, in the same year there were held courses sponsored jointly by the Board and the Institute of Chemistry, while courses in electrical engineering followed in 1924. Although negotiations were conducted around 1930 to try to bring into being national certificate courses in metallurgy, these did not materialise until 1945, the first ordinary national certificate examinations in the subject being held in 1946.

When the decade of the 1920s opened, any hopes there might have been for the expansion of facilities to give people better opportunities and better training for life were severely tempered by the prevailing climate of economic stringency. Some observers state that 'it was the aspirations of students rather than ... the manpower requirements of industry' which led to what limited demands there were for technical education. Where it existed at all, employers' support for technical education was more for the moral benefits brought by part-time study than for any particular skills that might be obtained.⁽⁴²⁾ P.W. Musgrave has commented that the Board of Education suffered cuts following the Geddes Committee of 1922 and again after the May Committee of 1931. Even later, 'since 1945 education has rarely had a high priority when cuts in the capital investments programme have been necessary'.⁽⁴³⁾

Soon after 1925 the Board of Education published an outline survey of the instruction which was then available in a number of technical subjects at levels suitable for 'technicians'.⁽⁴⁴⁾ As far as metallurgy is concerned this account makes dismal reading, with opportunities evidently few and the national attitude towards such instruction disinterested. Outside the universities and university colleges, there were then no full-time courses

(42) LAYTON, D., 'Education in industrialised societies'. In WILLIAMS, T.I. (ed.), A history of technology, vol.6, the twentieth century c.1900 to c.1950, part 1, (Oxford: Clarendon Press, 1978), 159.

(43) MUSGRAVE, P.W., 'Constant factors in the demand for technical education, 1860-1960'. Brit.Jrnl.Ednl.Studies, vol.14, no.2 (May 1966), 187.

(44) Education Survey (1927).

for intending technicians. Part-time grouped courses, on the other hand, were offered by a few institutions, among them

'the Municipal College of Technology in Manchester, the Applied Science Department of the University of Sheffield, the Sir John Cass Institute (in) London, and the technical schools in Birmingham and Wednesbury.'

These courses, which extended over five years of study, were 'attended occasionally by foremen as well as by persons looking forward to more responsible positions.'⁽⁴⁵⁾

Some centres provided innovatory-seeming classes 'for engineers interested in the treatment of metals', while others offered courses in iron-and-steel manufacture. Concerning these latter, however, the Board of Education report for 1924-25 commented

'it is not easy to require a suitable educational standard from students, or to devote adequate attention to the fundamental science which underlies the technology in which the students are primarily interested.'

The report also observed that 'the provision made for metallurgical craftsmen is not satisfactory'.⁽⁴⁶⁾ Apparently one of the problems encountered in providing local courses, especially in the non-ferrous branch of metallurgy, was the small number of those in industry prepared to teach. This reluctance was associated with fears of possible breaches of trade secrets.

In the 1920s and 1930s technical education received relatively little attention from Parliament, and the expenditure on all further education in 1920 was only six per cent. of the educational total, while in 1938 it amounted to a slightly-lower proportion.⁽⁴⁷⁾ During the period 1924 to 1929, when Lord Eustace Percy was president of the Board of Education, he directed the board to prepare surveys of individual industries and industrial districts, including their likely needs for technical instruction, and for

(45) Education Survey (1927), 57-58.

(46) Education Survey (1927), 57-58.

(47) MUSGRAVE, P.W., Technical education the labour force and education. (Oxford, etc.: Pergamon Press, 1967), 168-169.

this purpose he asked industrialists to state their requirements. The results were published in the form of pamphlets, such as that entitled Education for industry and commerce. The West Midlands metal working area. (48) Through the enquiries instituted at Percy's request into the position in Yorkshire there came into being, in some areas, regional committees which included industrial representatives. (49)

In 1926 came The education of the adolescent, a report of the consultative committee of the Board of Education. This committee sat under the chairmanship of Sir William H. Hadow (b.1859-d.1937), who had become principal of Armstrong College, Newcastle-upon-Tyne, in 1909, serving as vice-chancellor of the University of Durham in 1916-18, and transferring to the University of Sheffield in a similar capacity until 1930. (50) The Hadow Report advocated raising the school-leaving age from fourteen to fifteen, and providing 'secondary' education for all children. The findings were endorsed by the Board of Education, which encouraged local authorities to implement the recommendations that 'modern' schools should be made available to all those children aged eleven to fourteen who could not attend grammar schools. (51) For present purposes, the Hadow Report of 1926 is perhaps most relevant for its part in establishing some kind of secondary schooling as the norm in Britain, instead of the exception.

Later this work was built upon by another committee, whose report was produced in 1938: Secondary education with special reference to grammar schools and technical high schools. This time, the consultative committee of the Board of Education had as its chairman Will Spens of Cambridge University. The Spens Report recommended 'the expansion of the technical schools and the continued development of secondary education in separate grammar, technical and modern schools'. (52) The 'charter of the

(48) BOARD OF EDUCATION, Education for industry and commerce. The West Midlands metal working area. (London: HMSO, 1930).

Board of Education, educational pamphlets, no. 74, (industry series, no. 7).

(49) MUSGRAVE, P.W., loc.cit.

(50) MACLURE (1973), 179fn.

(51) LAWSON, John and SILVER, Harold, A social history of education in England. (London: Methuen, 1973), 393.

(52) MACLURE (1973), 193.

junior technical school', was how it was described at the time by the principal of the Constantine Technical College in Middlesbrough.⁽⁵³⁾

It was envisaged that the growth of technical facilities should aim to provide 'technical high schools' that were in every way equal in status with grammar schools; it was intended that recruitment to these new schools should be at the age of eleven-plus, 'by the same selective examination by which children are recruited to the grammar schools'.⁽⁵⁴⁾ This was a particularly thorny point, because until then the junior technical schools had suffered from the fact that their entrants were not chosen until the age of thirteen whereas the grammar-school pupils were selected at the age of eleven. Despite this handicap, however, one view was that the junior technical schools 'more than justified their existence'; and among employers 'there is general agreement ... that the typical junior technical school boy is a particularly good recruit for industry'.⁽⁵⁵⁾

It was proposed that the new 'technical schools' should be founded upon the existing 'junior technical schools' which had been established in 1913, but at the same time it was thought their value would be greatly enhanced by 'contact with the staff and the equipment of a technical college'.⁽⁵⁶⁾ During the 1930s the junior technical schools numbered about 100, and contained nearly 30 000 pupils, equal to between one and two per cent. of the school population, most of them drawn from the elementary schools.⁽⁵⁷⁾

Middlesbrough had a junior technical school which dated from 1919 and was used as a source of apprentice draughtsmen and other employees for the local steel works. Here, the entry age of thirteen for a three-year course was not to be altered to eleven for a five-year course until 1953.⁽⁵⁸⁾

(53) FIELD, H.V., 'The trend of technical education with special reference to engineering'.
Proc.Cleveland Instn.Engrs., (1939-40), 181.

(54) MACLURE (1973), 196; quoting from Spens Report, chap. 8, 294-295.

(55) FIELD, H.V., op.cit., 181-182.

(56) MACLURE (1973), 198.

(57) LAWSON, John and SILVER, Harold, op.cit., 407.

(58) LILLIE, W., The history of Middlesbrough.
(Middlesbrough County Borough Council, 1968), 446.

In the Lincolnshire iron-making district, Scunthorpe had a technical school which began day courses in 1936: there was said to be keen competition for places on the two-year technical course which each year took thirty students aged fourteen. Besides the subjects of English, history, geography and mathematics, some science was included together with engineering drawing and workshop practice.⁽⁵⁹⁾

In spite of the fact that from 1939 to 1945 Britain was plunged into a desperate war, Governmental efforts towards educational changes were not abandoned. By the spring of 1941 'outline plans for the post-war reconstruction of the educational system had been drawn up'.⁽⁶⁰⁾ There followed 'extensive consultation', and in 1943 a White paper on educational reconstruction was produced. This document proposed that the school-leaving age be raised to fifteen, a proposal which was implemented in 1947, and that for all children over the age of eleven-plus secondary education of equal standing be provided. In addition, as the departmental committee on juvenile education had done during the war of 1914-18, it recommended that:⁽⁶¹⁾

'When the period of full-time compulsory schooling ends the young person will continue under educational influence up to eighteen years of age, either by remaining in full-time attendance at a secondary school, or by part-time attendance at a young people's college.'

Many of the proposals of the 1943 White Paper became enshrined in law by the Education Act of 1944, legislation with which is associated the name of Mr. R.A. Butler, president of the Board of Education at the time. As a result of the 1944 Act, he became the minister of the new Department of Education, with responsibility for all education in England and Wales. However, up to 1981 there was to be no implementation of the proposal that all young persons should be obliged to continue some form of education to the age of eighteen.

(59) ANON., Technical education in Scunthorpe and district. Report of a committee of enquiry appointed ... by the Lindsey County Council Education Committee ... September, 1943. (June 1944), 10.

(60) LAYTON, D., op.cit., 168.

(61) MACLURE (1973), 206-207; quoting White paper on educational reconstruction, introduction.

The Education Act of 1944 dealt with the general structure and facilities for educational development of the country's children. As far as training for technology and science were concerned, there came the reports of two studies in the two years following its enactment: the Percy Report and the Barlow Report. Without doubt, these documents resulted from the new realisation, by politicians and by Government officials alike, that technology and science had proved vital for British survival in the war which was then just ending. After a long period in the wilderness, scorned by most schoolmasters and by the established professions, science and technology had suddenly achieved national value. As it was to turn out, this new status was to decline once more in the 1960s, during the years of apparent prosperity with their accompanying growth of complacency.

The Percy Report stemmed from a special committee on higher technological education appointed by the minister of education with the following terms of reference:⁽⁶²⁾

'Having regard to the requirements of industry, to consider the needs of higher technological education in England and Wales and the respective contributions to be made thereto by Universities and Technical Colleges; and to make recommendations, among other things, as to the means for maintaining appropriate collaboration between Universities and Technical Colleges in this field.'

The committee's report, Higher technical education, was published in 1945.⁽⁶³⁾ As pointed out by Dr. S.A.J. Parsons, the introduction to the report emphasised that Britain's position as a leading industrial nation 'was being endangered by a failure to secure the fullest possible application of science to industry, and that this was due to deficiencies in education.'⁽⁶⁴⁾ By recommending that a limited number of technical colleges should be encouraged to develop 'technological courses of a standard comparable with that of university degree courses',⁽⁶⁵⁾ the Percy Report

(62) MACLURE (1973), 226.

(63) MINISTRY OF EDUCATION, Higher technical education. (HMSO, 1945).

(64) PARSONS, S.A.J., The framework of technical innovation. (London: Macmillan, 1968), 141.

(65) MACLURE (1973), 228; quoting Higher technical education, section 3, 11-12.

laid out much of the groundwork upon which subsequently was to be developed the system of British polytechnics. It was envisaged that the courses at these colleges should be tailored to suit local industrial needs, and that instruction would be offered at several different levels: besides degree-level work there would be selected post-graduate courses together with part-time instruction of higher national-certificate standard.⁽⁶⁶⁾

The new atmosphere of interest in technology and science led the Ministry of Education in 1946 to publish a note on Research in technical colleges. This apparently suggested to local education authorities that it would be appropriate for teachers in technical colleges to undertake research, especially on topics closely connected with industry.⁽⁶⁷⁾ At the same time the ministry drew attention to the grants which the Department of Scientific and Industrial Research (DSIR) was prepared to make to encourage such activities.

The Ministry of Education was involved in the establishment of National Colleges designed for the needs of specific industries. The five colleges created in 1951 dealt with horology, foundry work, heating and ventilating, rubber technology, and aeronautics. Of these, the two for foundry technology and aeronautics were directly promoting aspects of metallurgy, while the National College of Rubber Technology, although concerned with non-metallic substances, nevertheless shared the common interest in materials for engineering purposes. The National College for Foundry Technology was set up at Wolverhampton, while the College of Aeronautics was opened at Cranfield, near Bedford, in 1946. At the latter institution a lecturer in metallurgy was included on the academic staff at the outset, while a department of materials headed by a professor was to come into being c.1957, at a period when the principal of the institution, Dr. A.J. Murphy, was also a metallurgist.

In some years after 1950 the Ministry of Education was to encourage metallurgical instruction in a positive manner by holding short courses for teachers. For instance, in July 1954 a ten-day course 'for teachers from

(66) MACLURE (1973), loc.cit.

(67) PARSONS, S.A.J., op.cit., 161.

technical colleges' was arranged at the County Technical College in Wednesbury, while in July 1961 teachers met for a similar purpose at the College of Advanced Technology in Birmingham. In 1962 'engineering metallurgy' was the title of one section of the summer school held at Cranfield College of Aeronautics; the following year the Ministry of Education offered two short courses, one on 'metal fabrication' for those involved with teaching City and Guilds' courses, and the other for teachers of engineering subjects. In 1964 a course for metallurgy teachers was held at the Sheffield College of Technology. By 1970, however, these useful measures to stimulate teaching were to be dropped. In many respects the short courses are reminiscent of those organised in South Kensington 85 years earlier by the Ministry of Education's predecessor, the Science and Art Department. Another way in which the Ministry of Education was to aid metallurgical teaching in the years soon after 1950 was by including foundry work and general aspects of metallurgy in the training courses for technical teachers which were available at Bolton and Huddersfield.

Throughout the century 1851 - 1950, the direct influence of the Government's education office upon the universities in England and Wales was small. With some exceptions, Government grants to the universities and university colleges were made by the Treasury without regulation by the administrative machinery of 'Education'. In 1889 the first Treasury Grants to university colleges amounted to £15 000, while for the year 1945-46 the sum was £5 million.⁽⁶⁸⁾ Only in the period between 1911 and 1919 did the Board of Education share with a Committee of Grants responsibility for determining the distribution of the money; for a number of years before this, university colleges benefited by grants given for science classes started under the auspices of the Science and Art Department. For example, as cited by Michael Argles, in one year close to 1900, Sheffield University College had 2170 students of various subjects, of whom 142, or less than seven per cent., were engaged in work of degree standard.⁽⁶⁹⁾

(68) ARGLES (1964), 49, 71.

(69) ARGLES (1964), 49.

State aid to individual students increased substantially during the hundred-year period. From 1920 'state scholarships' were distributed on a competitive basis: from 200 awarded in the first year, the number rose to 360 in 1936.⁽⁷⁰⁾ In the years around 1950, the Ministry of Education offered 120 'technical state scholarships' to help students at technical colleges and other establishments to attend selected courses at universities.⁽⁷¹⁾ Local-authority scholarships were also available to some extent; begun in the 1890s, these also became more numerous as the years progressed. In 1937-38 the proportion of full-time university students in England that received assistance was 39 per cent.⁽⁷²⁾

Metallurgy is concerned with aspects of technology. Taken altogether, it may be concluded that State encouragement of technology through the medium of its education office was less than whole-hearted for at least 95 years of the period 1851 - 1950. In the first half of the period, although the Department of Education showed great reluctance to be associated with any scheme that promoted trades or crafts, support was given to instruction in scientific principles. State fostering of science through the Science and Art Department during the second half of the nineteenth century certainly produced results: from virtually nothing in 1851, by 1900 a system of classes and examinations in science had grown up which must have afforded satisfaction not only to the politicians and civil servants connected with the schemes, but to many thousands of the toiling masses as well, who attended the evening and Saturday classes after arduous hours of work. Day-time science classes also benefited from the department's grants, and 'school science' was substantially encouraged by both the department's classes and its share in training science teachers. However, sharp criticism was, and still is, levelled at the Science and Art Department for its rigid and exclusive adherence to 'science' rather than admitting a leavening of technology into the courses it was prepared to support; this attitude was forced upon the

(70) LAWSON, John and SILVER, Harold, A social history of education in England. (London: Methuen, 1973), 402.

(71) ANON., 'Technical state scholarships'. Bull.Instn.Metallurgists, vol. 4, no. 3 (August 1953), 23.

(72) LAWSON, John and SILVER, Harold, loc.cit.



department by the prevailing national political and social climate which was completely opposed to any suggestion of subsidising specific industrial activity. Nonetheless, after 1862 'metallurgy' was among the score of subjects which the Science and Art Department supported by making payments to teachers and towards the cost of obtaining appropriate equipment, as well as by instituting an examination system which included incentive prizes to candidates. These State actions brought formal metallurgical instruction within the reach of those who were able to attend the small number of centres where tuition was offered, and it opened the competitive examinations to others who pursued private, informal study. Moreover, in the last four decades of the nineteenth century the inclusion of metallurgy in the Science and Art Department's system of classes and examinations meant that, through the official yearly published syllabuses, the subject was repeatedly brought to the notice of all who were concerned with promoting technical instruction in England and Wales. Consequently, if and when local tuition in the subject was offered, it was likely to be based upon the 'South Kensington' model.

After 1901 the reluctance of the education office to be seen to be drawn in to the direct promotion of trade, craft, and 'technician' instruction continued, although the selective nature of the grants made to support tuition was abandoned. The Science and Art examinations were phased out and, in their place, the education office tried to persuade authorities in the various districts to set up equivalent formal training schemes. There also came, after 1913, the provision of 'junior technical schools', and the raising of the minimum school-leaving age to fourteen. In the 1920s encouragement was given by the education office to the formation of national certificate schemes jointly with other organisations. The office worked to bring about such an academic training and accreditation scheme for metallurgy but unfortunately was unable to achieve this until the last five years before 1950.

At any rate throughout the second half of the nineteenth century, all public funds channelled through the Science and Art Department into the kingdom-wide promotion of knowledge of scientific principles were aimed at helping those prepared to help themselves, for the department relied upon the injection of local funds and resources to form bases to which the State then contributed.

Overall, the Government's actions made through its education office

exercised a considerable long-term influence. It was mostly of a 'background' character, with metallurgy given no precedence over a large number of other subjects, but with a good deal of progress achieved in raising the levels of general education and establishing the pattern by which formal tuition in scientific and technical subjects might be obtained.

CHAPTER 5GOVERNMENT INFLUENCE THROUGH NON-MILITARY
CHANNELS OTHER THAN THE EDUCATION OFFICE

Nowadays it seems natural to associate State sponsorship of instruction with the Department of Education and Science, but in fact there are other Government sectors which make notable contributions to the diffusion of knowledge, one example in recent years being the Department of Employment with its industrial training boards. In 1964, when the training board for the iron-and-steel industry was formed, it was one of the first four of its kind, and there were expectations that a total of between thirty and forty would be set up.⁽¹⁾ In earlier times, because State expenditure through the Board of Education was at much lower levels than has been the case latterly, the contributions of other Government departments constituted a greater proportion of the whole. In addition to civil activities, State expenditure for military purposes has contributed notably to metallurgical development: this chapter, however, is limited to civilian aspects.

Considering first the situation prevailing in the 1850s, the Science and Art Department and the Government School of Mines both owed their founding to agencies other than the education office. Indeed, an education department was only established officially in 1856. At the time of its opening in London in 1851, the Government School of Mines was the only British institution to offer instruction in 'metallurgy'. The school was closely linked with the Geological Survey, and its formation can be largely attributed to Henry Thomas De la Bêche (b.1796-d.1855), who had earlier succeeded in obtaining Government recognition of his scheme for a Geological Survey of England and Wales; in 1835 the Board of Ordnance and the chancellor

(1) Colliery Guardian, vol. 208, no. 5379 (22 May 1964), 692;
BURY, M.O., 'The iron and steel industry training board'.
Jrnl. Iron Steel Inst., vol. 206 (May 1968), 453.

of the exchequer had agreed that public funds should be expended on the project, and De la Bêche was appointed to organise it.⁽²⁾ Two years later, the chancellor of the exchequer had approved a suggestion that it would be nationally advantageous to display in a museum rocks and minerals of economic significance. Acceptance of this proposal was helped by the fact that in 1838 a commission had been appointed to recommend the best stone for the new Houses of Parliament at Westminster and, as a result, large numbers of specimens became available. Government then assigned a building near Whitehall which by 1839 was in use and in 1841 was opened to the public as the Museum of Economic Geology; to it was attached a Mining Record Office. Both have significance in the present context. Although the Geological Survey headed by De la Bêche was at that period a part of the Ordnance Survey, administratively the facilities of the museum and record office were within the Office of Woods, Forests, and Works. The Geological Survey was transferred to this latter department by a Treasury minute prepared by Sir Robert Peel and dated 27 December 1844.⁽³⁾

The first curator and chemist of the museum was an experienced man, Richard Phillips, FRS, whose functions included making analyses of metallic ores and other minerals and soils for the public 'on very moderate terms'. Around 1845, Dr. Lyon Playfair (b.1818-d.1898) was appointed to the staff of the Geological Survey as chemist in surroundings of unattractive intrigue. From 1841, small numbers of pupils were 'received for instruction in analytical chemistry, metallurgy, and mineralogy'.⁽⁴⁾ As Dr. Buckland, professor of geology in the University of Oxford, expressed it early in 1841 in his presidential address to the Geological Society, 'The pupils in this laboratory are already actively employed in learning the arts of mineral analysis and the various metallurgic processes'.⁽⁵⁾ This must be regarded as the beginning of instruction under Government auspices, even if it was on an extremely-limited scale and an informal basis.

(2) BAILEY, Sir Edward, Geological Survey of Great Britain.
(London: Murby, 1952), 26; quoting LYELL, Charles, president
of the Geological Society, at meeting of society, 20 Feb.1836.

(3) CHAMBERS, Sir Theodore C., Register of the associates and old students
... of the Royal School of Mines ... with historical
introduction (London: Hazel, Watson and Viney, 1896), ix.

(4) CHAMBERS, T.C., loc.cit.

(5) CHAMBERS, T.C., loc.cit.; quoting Proc.Geol.Soc., vol.3, 211.

Treasury sanction had been granted in 1839 for public lectures on practical aspects of geology, but action to put such lectures into effect was not taken until more than ten years later, when new premises were occupied. In the Mining Record Office, situated next door to the museum, were exhibited models of mines, of machinery for working them, and of metallurgical operations. There were also samples of materials at various stages of treatment, and specimens of finished products such as 'castings, electrotypes, (and) gun barrels'.⁽⁶⁾ As Dr. Buckland summed it up:⁽⁷⁾

'From all of these the public may receive valuable ... information as to the mode of occurrence of minerals within the earth ... and the machinery by which coal and metallic ores are ... fitted for the market.'

During the late 1840s, at the time that Robert Peel was Government spokesman in the Commons, more spacious premises for the museum and the rest of the Geological Survey were built between Piccadilly and Jermyn Street: this, the first important structure in Britain designed for occupation by the staff of a purely technological or scientific institution,⁽⁸⁾ was erected at State expense. The building was formally opened on 12 May 1851 by Prince Albert, less than a fortnight after the Queen had opened the Great Exhibition in Hyde Park one kilometre to the west. Already, in the spring months of 1851, a series of five or six public lectures had been delivered. These were destined to be the first of a long line which stretched through the whole of the second half of the nineteenth century, ending only in May 1900.⁽⁹⁾ According to a work published twenty years after 1851,⁽¹⁰⁾ the institution of these lectures was

'due to the enlightened foresight of the Minister under whose instructions the school was founded, and who stipulated expressly that the professors should deliver annually, at a nominal admission fee, a course of lectures to working men.'

It seems likely this was an allusion to Sir Robert Peel the younger, (b.1788-d.1850).

(6) BAILEY, E., op.cit., 30.

(7) CHAMBERS, T.C., loc.cit.,; quoting Proc.Geol.Soc., vol.3 (19 Feb.1841),471.

(8) FLETT, J.S., The first hundred years of the Geological Survey of Great Britain. (London: HMSO, 1937), 51.

(9) BALFOUR, Graham, The educational systems of Great Britain and Ireland. (Oxford: Clarendon Press, 2nd edn. 1903), 255.

(10) BECKER, Bernard, Scientific London. (London: H.S. King, 1874), 183.

Six months after the new museum's opening, on 6 November 1851 there was inaugurated within it the Government School of Mines and of Science applied to the Arts, as the institution was at first styled: from 1863 it was known as the Royal School of Mines. Metallurgy was one of the subjects in which instruction was offered from the outset, a medical doctor, John Percy MD (b.1817-d.1889), being appointed to teach it. Percy's introductory lecture, which was later included in a published volume, Records of the School of Mines, was entitled 'On the importance of special scientific knowledge to the practical metallurgist'.

Government support, both as hard cash from the Treasury and in the form of well-disposed influential persons, brought into being these facilities for metallurgical instruction. Even so, the support was by no means uniform. This is illustrated by a comment included in a letter written in 1852 by the school's teacher of natural history applied to geology and the arts, Edward Forbes: 'to some extent we are fighting with disadvantages for the Woods and Forests, or rather Lord Seymour, do nothing to push us on'.⁽¹¹⁾ In the event, the office of Woods, Forests, and Works had little further opportunity to 'push on' the School of Mines, for in 1854 the school, together with the other sections of the Geological Survey and Museum, was transferred to the care of the Board of Trade.

Government had officially recognised an interest in trade and commerce the previous century, in 1786, when a 'committee of the Privy Council of trade' was constituted. Fifty years later, at much the same time that De la Bêche's Geological Survey had been created, the Committee of Trade recommended establishing a school of design, for which the Commons voted £1500. Subsequently, increased sums were granted, and more schools of design were started in various parts of the country, their object being to improve the competitiveness of the nation's exports.⁽¹²⁾ Early in 1853, because of the desire among some parliamentarians to promote scientific knowledge within Britain, the Committee of Trade determined that the scope

(11) CHAMBERS, T.C., op.cit., xiii.

(12) BALFOUR, Graham, op.cit., 155.

of the existing Department of Art should be widened by inclusion of 'science'. Thus there came into being the Science and Art Department which, except for some small sums, was by itself to represent State aid for civil technical instruction in England and Wales for the next third of a century. The School of Mines, the Museum of Practical Geology, the Mining Record Office and the remainder of the Geological Survey all became parts of the new department. A few years later, in 1857, all received another administrative transfer, this time to the new Education Department, through which Governmental influence was intended to be concentrated.

In the aftermath of the Great Exhibition, Parliament voted £150 000 to add to the exhibition's profits and so enable three estates in Kensington to be purchased: Gore House, Villiers and Harrington.⁽¹³⁾ In due course, part of this land in the hands of the exhibition commissioners was to form the home of the Royal School of Mines as well as of other establishments concerned with metallurgy, such as the Science Museum, the Geological Museum, and the departments of engineering and aeronautics at the Imperial College of Science and Technology.

The thirty-year period from 1851 was a difficult time for the distinctive instruction, including metallurgy, offered by the Royal School of Mines. Repeatedly, the system was jeopardised by pressure from those in influential quarters who wished the assembled facilities and talents to be used for spreading knowledge of general science to wider numbers of students. After thirty years of uncertainty, around 1880 this was the view advanced for the Science and Art Department by J.F.D. Donnelly; at that time it was vigorously opposed by only two remaining original members of the staff, W.W. Smyth in charge of mining, and Dr. J. Percy, the metallurgist. Percy resigned rather than submit to the changes proposed. Then in his sixties, Percy behaved as if a complete outcast from the corridors of political power: but a dozen years before, from 1865, in addition to his teaching duties he had held the appointment of ventilation superintendent to the Houses of Parliament, a position said to entail his attendance at Westminster every afternoon during the session.⁽¹⁴⁾

(13) ARMYTAGE, W.H.C., 'Lyon Playfair and technical education in Britain'. Nature, vol. 161 (15 May 1948), 752.

(14) Obituary, Dr. John Percy. Jrnl.Iron Steel Inst., (1889), no.1, 211.

At this critical juncture, however, the Royal School of Mines' stalwarts still retained friends somewhere, for in replying to Donnelly's proposals, the Lords of the Treasury, represented by Lord Frederick Cavendish, stipulated that any scheme for modifying the school into the proposed National School of Science should avoid a complete merging of the 'strictly technical and professional school of mining knowledge in a more general scientific institution.' The justification given for retaining the identity of the school was that:⁽¹⁵⁾

'The development of the mineral riches of this country and of its colonies and dependencies was ... the foremost object to which the Government intended by its measures in 1851-53 to direct the researches of science and to apply their results.'

This Government influence prevented the extinction of metallurgy as an independent academic subject in Britain when only one third of the century 1851 - 1950 had passed. During the later 1880s and the 1890s, opportunities for metallurgical instruction multiplied in a number of places, but the position of the subject in South Kensington remained insecure until the reorganisation which brought into being the Imperial College of Science and Technology in 1907, with the Royal School of Mines firmly recognised as one of the three constituent parts.

Besides its connexion with the early years of the Science and Art Department, the Government's trade section was several times involved with official enquiries which had a bearing on technical instruction. For instance, such instruction was considered by the Royal Commission on the Depression of Trade and Industry, whose second report was published in 1886. This report included evidence from a number of people directly involved with iron and steel: the general manager of the Barrow Hematite Steel Co., the Sheffield master cutler, Sheffield steelmakers Samuel Osborn and T.E. Vickers and, from Middlesbrough, Sir Isaac Lowthian Bell. Closely questioned by the commission on the position of technical instruction in Sheffield, Willis Dixon, president of the Sheffield Chamber of Trade, admitted that up

(15) ANON., Centenary of the Royal School of Mines 1851-1951.
(London: the School, 1951), 21.

to that time in the early 1880s none was available, although he was a committee member of the new technical school which was then being started in the town, 'intended for the workmen's sons and foremen and manufacturers' sons.'⁽¹⁶⁾ Specifically on apprenticeship, this witness stated 'they get no technical education whatsoever except what they learn in the factory' and, as a 'master', he repudiated all personal responsibility for the progress of the apprentices, which he thought was a matter between them and the workmen.⁽¹⁷⁾

Thirty years later, during the economic crisis associated with the Great War of 1914-18, the Board of Trade appointed departmental committees to consider the post-war position of various industries such as engineering, electrical trades, and iron and steel. The report on the engineering trades, published in 1918, expressed the view that the standard of industrial apprenticeships should be raised. It was proposed this should be done by the exercise of greater care on the part of employers, and by 'not less than one-third' of 'the most promising boys' being selected to attend organised technical classes as part of their training. At the same time, the report opposed the wholesale compulsion of youths to attend such classes, on the grounds that not all would benefit.⁽¹⁸⁾ Turning to higher technical education, the engineering report was forthright; while the universities were doing admirable work, especially in the engineering districts, they were 'restricted in their endeavours both by want of sufficient Government monetary support, and by want of sufficient inducement to encourage the stream of students.' This latter point was elaborated:⁽¹⁹⁾

'the monetary results which can be achieved by a graduate of the technical and scientific side of these Universities appear to us wholly incommensurate with the expenses incurred, and the time and labour involved in procuring that education.'

(16) ROYAL COMMISSION OF INQUIRY ON THE DEPRESSION OF TRADE AND INDUSTRY, Second Report (1886), Parl.Papers, 1886, 20.

(17) ROYAL COMMISSION ... ON THE DEPRESSION OF TRADE, op.cit., 21.

(18) DEPARTMENTAL COMMITTEE OF THE BOARD OF TRADE ON ENGINEERING, Report of the departmental committee appointed by the Board of Trade to consider the position of the engineering trades after the war. (HMSO, 1918), Cd. 9073. 15.

(19) DEPARTMENTAL COMMITTEE OF THE BOARD OF TRADE ON ENGINEERING, op.cit., 16-17.

The engineering report went on to explain that hitherto it had been possible for British employers to pay low wages to knowledgeable young German scientists, particularly chemists. It added that, as far as possible, the engineering trades should employ persons of British university training in all positions that involved technical and scientific attainments. This report, produced at the request of the Board of Trade, thus drew attention to a major restraint on technological improvement that was to continue to have an inhibiting effect for at least a further thirty years, into the 1950s.

The corresponding war-time departmental committee for the iron-and-steel trades included some leading steelmakers: Sir Hugh Bell, Benjamin Talbot, Henry Summers and, until his death in December 1916, Archibald Colville. Another member was John Hodge, a prominent labour leader who, by the time the report was published in 1918, had been appointed first minister of labour. The chairman was G. Scoby-Smith, pre-war commercial adviser to the Cleveland company Bolckow, Vaughan. According to the committee's report, which was dated June 1917, ⁽²⁰⁾

'The question of technical education in relation to the iron and steel industries has formed one of the main heads of the committee's investigations. Evidence ... tends to show a growing feeling of dissatisfaction with the lack of systematized technical instruction upon a scale commensurate with the needs ... '

Like its counterpart in engineering, this report recommended a substantial increase in the amount of organised technical instruction given to school-leavers entering industry. In some other respects, however, it was more sweeping in the changes proposed, the first of these being the raising of the school-leaving age from fourteen to sixteen years. Linked with this was the proposal for a system of industrial 'apprenticeship' which would be 'in the nature of a general agreement of service under a particular employer, to begin at the age of fourteen'.⁽²¹⁾ To some extent these

(20) DEPARTMENTAL COMMITTEE OF THE BOARD OF TRADE ON IRON AND STEEL, Report of the departmental committee appointed by the Board of Trade to consider the position of the iron and steel trades after the war. (HMSO, 1918), Cd.9071. 39.

(21) DEPARTMENTAL COMMITTEE ... ON IRON AND STEEL, op.cit., 40.

proposals paralleled the recommendations of the Board of Education's war-time committee that the school-leaving age should be raised to fourteen without exception and that extending beyond this age for several years some form of studies should be continued.

For the first two years of the steel trades' proposed agreement, which was envisaged as being for a total term of seven years, the employer would make small payments to a youth to enable him to remain at school. Then, during the subsequent two years, the 'apprentice', now in the works, would attend regular technical classes as part of his duties. It was suggested such classes might well be taught by some of the works' staff, and that Monday morning might be a suitable time to hold at least a portion of them, for then the plant would not have resumed full production after the weekend, and the brains of the trainees might be reasonably alert. By these proposals, from the age of eighteen a youth would not necessarily receive further training, but by his agreement would be bound to work for the same employer for three more years.

However, it was recognised that in cases of exceptional aptitude or diligence, continued instruction after the age of eighteen might be desirable, although it was not made clear where the necessary finance for such 'university type' advanced training was to come from. The committee did advocate 'a considerable extension' of such training, pointing out that the activities of the British iron-and-steel industry were mostly carried on within a limited number of well-defined districts. It recommended that in each of these

'there should be created a technical institute approximating to the university type, in order to provide an advanced technical training to those employed in local industries whose means admit only of local or part-time study.' (22)

The committee, moreover, urged the desirability of what have since come to be known as 'sandwich courses', expressing the view that technical instruction at universities should be interspersed with periods of practical

training made possible by the co-operation of large employers. At the same time, it was considered there should be close links between the technical universities, the local teaching centres, and the industries they served. The reason was that ⁽²³⁾

'The iron and steel industries can only reap the full benefit of scientific progress by the constant application of technical knowledge to the practical problems of industry; and conversely technical training of a purely theoretical character is of little value unless combined with a considerable measure of works' experience.'

Certain of the proposals of these Board of Trade war-time committees, where they reinforced the views of the Board of Education, came to be incorporated in the 'Fisher' Education Act of 1918, for example that the school-leaving age should be raised to fourteen, and that some form of attendance at classes should continue to the age of eighteen. But these recommendations, like so much of the remainder, made little progress during the lean years of the 1920s and 1930s. The steel-making areas of North Lincolnshire and Cleveland were without day-time technical colleges, let alone institutions 'approximating to the university type', until after 1929, while the North Wales district round Shotton did not obtain its technical college, at Connah's Quay, until 1954. ⁽²⁴⁾ In 1922-23, apart from undergraduate courses for B.Sc. degrees, full-time courses in metallurgy were available only at Sheffield, Birmingham, and Chelsea Polytechnic, though evening classes in the subject were offered at about a dozen other places; these included Dudley, Wolverhampton, Wednesbury, Smethwick, Swansea Technical College, Middlesbrough High School for Boys, and Manchester Municipal College of Technology. ⁽²⁵⁾

Compared with the meagre provisions that existed for formal instruction in metallurgy, however, there were considerably more opportunities for studying engineering, chemistry, and commerce, all of which were, and are,

(23) DEPARTMENTAL COMMITTEE ... ON IRON AND STEEL, loc.cit.

(24) DENT, H.C., The year book of technical education ... 1958.
(London: A. & C. Black, no date), 471.

(25) BOARD OF EDUCATION, List of the more important technical schools ... recognised by the Board ... (HMSO, 1925), 1-39; 71-72.

important contributors to the success of any steel works or other industrial metallurgical undertaking.

In 1924 prime minister J. Ramsey MacDonald set up a committee on industry and trade 'to inquire into the conditions and prospects of British industry and commerce, with special reference to the export trade'. The chairman of this committee was Sir Arthur Balfour (b.1873-d.1957), a Sheffield steel merchant, and master cutler in 1911, who was to serve later, between 1937 and 1946, as chairman of the Council for Scientific and Industrial Research. In the third section of the committee's report to be published, Factors in industrial and commercial efficiency (1927), one of the seven chapters, entitled 'training and recruitment', considered apprenticeship, technical and commercial education, and vocational guidance. In the paragraphs devoted to the supply and demand for technically-trained staff in the iron-and-steel industry, the report concluded that 'On the whole ... of recent years the supply of engineers and technical chemists has exceeded the demand.'⁽²⁶⁾ This conclusion was attributed to the combination of the prevailing industrial depression and an unusually-high output from the universities in the years immediately following the Great War. By contrast, in the very next sentences the report gave a better prospect for graduate metallurgists; it stated that, due to industrial realisation of the need to replace 'traditional methods' by 'those based on the recent remarkable developments in metallurgical science', there had been 'an increased demand for young metallurgists with the highest scientific qualifications - a demand which has sometimes tended to exceed the supply.'⁽²⁷⁾ The fourth and final part of the Balfour Committee's report was published in 1928 as a Survey of metal industries. This contained chapters on iron and steel, engineering, electrical manufacturing, and shipbuilding. It cautiously reiterated the doubt 'whether the number undergoing university training in metallurgy is equal to the real needs of the industry in the future.'⁽²⁸⁾

(26) COMMITTEE ON INDUSTRY AND TRADE, Factors in industrial and commercial efficiency being part one of a survey of industries with an introduction by the committee. (HMSO, 1927), 200.

(27) COMMITTEE ON EDUCATION AND TRADE, op.cit., 201.

(28) COMMITTEE ON INDUSTRY AND TRADE, Survey of metal industries being part four of a survey of industries. (HMSO, 1928), 37.

At much the same time that the Balfour Committee on Industry and Trade was in being, the Ministry of Labour instituted an enquiry into the extent of apprenticeship and training for skilled occupations. Of the seven reports published by this enquiry, one was concerned with metal extraction, as well as with mining, quarrying, and the chemical, glass and pottery industries, while another included metal industries together with engineering and ship-building. In the Board of Education, during Lord Eustace Percy's presidency, there was also activity in the second half of the 1920s, preparing surveys of individual industries, industrial districts, their likely needs for technical instruction, and how these needs were being met at the time. Altogether, the question of training for industry received attention from a number of Government sectors in the period 1915 - 1930.

Another part of British industrial administration which experienced radical changes in the 1850s was the 'patent' system, which had then been in existence for more than 200 years. Following the deliberations of a Select Committee of the House of Commons in 1851, the lord chancellor and leading Government lawyers were appointed 'commissioners of patents' in 1852. Initial patent fees were substantially lowered, and the Office of the Commissioners of Patents and Inventions was soon dealing with over 2000 applications a year. In 1883 further changes were effected through a Bill introduced by Mr. Joseph Chamberlain, at that time president of the Board of Trade; from January 1884 the patent office became the Board of Trade's responsibility. Besides the extensive work of examining applications, considerable sums were spent in compiling and publishing summaries of British patent specifications grouped according to subject. The numerous categories included 'iron and steel manufacture' (serial no. 72), 'metals and alloys (excepting iron and steel)' (no. 82), 'metals, cutting and working' (no. 83), 'sifting and separating' (no. 117), 'electrolysis' (no. 41), and 'furnaces and kilns' (no. 51). This effort, which by 1910 covered all printed patent specifications filed between 1855 and 1904, involved publishing more than 1100 volumes.⁽²⁹⁾ It meant that a modest shilling (£0.05) would

(29) HARDING, H., Patent Office centenary a story of 100 years in the life and work of the patent office. (HMSO, 1952), 10-11; 26; 32-33.

enable a reader to possess a book of illustrated abstracts of five years' British patents within a particular category. The patent office's usefulness was not confined to patent specifications, however: from the late 1850s, and extending throughout the remainder of the period considered, the library of the patent office was available to the public, affording a valuable source of metallurgical information with its open shelves of periodicals and textbooks, as well as patent specifications of many nations. In the 1950s this State-run free reference library was to remain open until nine o'clock on week-day evenings and four o'clock on Saturdays.

The British Museum in London, although run by a group of trustees, received State grants. Government participated in erection of the new reading room and surrounding bookstacks, opened in 1857. Ostensibly admission then, as now, was given to all who claimed a serious purpose of study, but during the middle decades of the nineteenth century there were complaints of restrictions.⁽³⁰⁾ Moreover, in those years the museum's library was open only during week-day hours of daylight. In the spring of 1880, when experimental electric lighting was being tried in the reading room, the editor of the weekly periodical Iron made sure his readers were aware of the facilities already available to them, as well as the improvements which he considered should be made for the benefit of the 'intelligent artisan'.⁽³¹⁾ More widely, Acts of 1850 and 1855 empowered local councils to provide public libraries, raising funds by means of a penny rate (£0.004). Manchester was one of the earliest towns to take advantage of this provision and gradually others followed, although libraries supported by local rates did not become common until near the close of the nineteenth century, and it seems likely that only exceptionally was worthwhile metallurgical literature made available by these means.

(30) MILLER, Edward, 'Education: public libraries', in SUTHERLAND, G. and others (eds.), Education government and society in nineteenth-century Britain. (Dublin: Irish Univ. Press, 1977), 127; 133, note 13.

(31) Iron, vol.15 (Jan.-June 1880), 13; 205; 258.

The quantity of metallurgical work carried out by Government for civil purposes was much less than that related to the production and supply of equipment for the country's military objectives. One non-military Government-run metallurgical establishment, however, was the Royal Mint. From around 1810, this was situated on the original site of Eastminster Abbey on Little Tower Hill, outside, but beneath the walls of, the Tower of London,⁽³²⁾ where new equipment had been brought into use. A Royal Commission of 1848 enquired into the 'constitution, management and expense' of the Mint, with the result that the office of master became incorporated with that of chancellor of the exchequer, while a 'deputy master and comptroller' took practical superintendence. At the same time the work of minting, which had formerly been done on contract, was brought entirely into the hands of full-time State employees. The quantity of new coins required in 1851 was about 25 million; by 1900 the figure had grown to 130 million, while by 1950 it had increased another three-fold to 400 million.⁽³³⁾ The year 1961 was to see a coinage production of double this quantity again, with 298 million for Britain and 538 million for overseas governments.⁽³⁴⁾ Following the Coinage Act of 1870 Dr. Percy, in charge of metallurgy at the Royal School of Mines, was appointed an adviser and referee.

Throughout the hundred years under review, metallurgical skills were required for determining the composition of all materials entering and leaving the Royal Mint, for maintaining coinage of uniform^{and}/standard properties, and for devising fresh alloys demanded by political or economic changes, as for instance the replacement in 1946 of silver-based coins by those of cupronickel. In addition, staff at the Mint made significant contributions to metallurgical research. Thus, in the years between 1865 and his death in 1870, the master, Professor Thomas Graham, investigated the effect of gases dissolved in metals. This was followed during the 1870s by work done by

(32) NEWMAN, W.A.C. and STRIDE, H.G., 'The Royal Mint'.
Bull.Instrn.Metallurgists, vol.2, no.8 (Dec. 1950), 17.

(33) STRIDE, H.G., The Royal Mint an outline history.
(HMSO, 1951), 12-13.

(34) NORTHCOTT, L., 'Presidential address - metallurgy and the civil service'. The Metallurgist, vol. 2, no. 10 (July 1963), 231.

Graham's former private assistant and successor as chief technologist William Chandler Roberts, ARSM, (later W.C. Roberts-Austen), who was appointed chemist to the Mint in 1870 and whose studies of binary alloys of silver and copper resulted in the publication of one of the first 'freezing-point curves'. In 1880, while retaining his post at the Mint, Roberts-Austen became professor of metallurgy at the Royal School of Mines. His continued research at the Mint was on the effects that small proportions of other elements had on gold, and it led to a request from the Institution of Mechanical Engineers that Roberts-Austen should extend the investigation with funds supplied by the institution. This work occupied the 1890s and yielded a series of 'alloy reports' which were published by the Institution of Mechanical Engineers. The laboratory space and part of the equipment were provided by the Mint. Early in the present century the investigation was transferred to the newly-opened National Physical Laboratory, but some metallurgical research work concerned with improvements in methods for assaying and refining precious metals continued to be done in the Mint by its staff.⁽³⁵⁾ Throughout the first half of the twentieth century close links were maintained between the metallurgical staff at the Royal Mint and the Royal School of Mines. Similar links existed between the Mint and the nearby Sir John Cass Institute where at least one member of the Mint's staff, Mr. W.A.C. Newman, served as a part-time metallurgy lecturer.

The Royal Mint was a factory whereas, by contrast, the National Physical Laboratory, which opened in 1900, was essentially concerned with experimental work; it was the British Government's first venture into the direct encouragement of national technology and science by helping industrialists to improve their products and techniques. The laboratory's origins can be traced at least from the early 1870s: the Royal Commission of 1872, named the 'Devonshire Commission' after its noble chairman, was partly brought into being in consequence of the persuasive lobbying of an army officer, Colonel Alexander Strange, FRS (b.1818-d.1876). Strange, after his return from service in India in 1861, actively promoted science; interviewed by the commission, he advanced the idea that the State should establish a 'science museum' together with laboratories for metallurgy as

(35) HAUGHTON, J.L., 'Metallurgical research in government laboratories', in Proc. (First) Empire Mining Metall. Congress, part 5, non-ferrous metallurgy, (London, 1925), 107.

well as for chemistry, physiology, astro- and geo-physics. He also urged State endowment of the universities. These personal views were largely endorsed and enshrined by the commission in its Eighth report.⁽³⁶⁾ In due course, a national science museum was established, but, in the first half of the twentieth century, it remained administratively within the education office. Also stemming from the commission, late in 1876 Government funds to the extent of £4000 a year were made available for research, under the control of the Royal Society. This was the beginning of State encouragement which, by 1930, had become a substantial factor in British technological and scientific research.

During the 1890s the desirability of a British State-sponsored research institution received useful stimulus from the opening in Germany in 1895 of the Charlottenburg Physikalisch-Technische Reichsanstalt with its staff of about 80.⁽³⁷⁾ Accordingly, in 1897 the Treasury appointed a committee to consider the matter, the committee's report was produced in 1898,⁽³⁸⁾ and in 1900 a testing establishment was founded. Named the National Physical Laboratory, or 'NPL', it occupied Bushey House at Teddington, west of London, an old royal residence granted for the purpose by the Crown.⁽³⁹⁾ Significantly, in the USA, the National Bureau of Standards was created at much the same time, in 1901. At British Treasury request, control of the NPL was effected through the Royal Society, although the committee included representatives of the Board of Trade and certain technical societies. Initial State aid of £12 000 was agreed for erection of suitable buildings, together with £4000 a year for five years towards income. By 1915 this yearly sum had increased to £7000.⁽⁴⁰⁾ It was expected other income would come as fees from industrial testwork and advice.⁽⁴¹⁾

(36) CARDWELL, D.S.L., The organisation of science in England.
(London: Heinemann, 1972 edn.), 122; 125.

(37) CARDWELL, D.S.L., op.cit., 177.

(38) CARDWELL, D.S.L., op.cit., 185.

(39) ANON., 'Metallurgical research at the National Physical Laboratory'.
Iron Coal Tr.Rev., vol.158, pt.4238 (3 June 1949), 1232.

(40) APPLETON, Sir Edward, 'The organization and work of the Department of Scientific and Industrial Research'. Jrnl.Inst.Metals, vol.75 (1948-49), 974.

(41) SUTTON, H., 'Metallurgy at the National Physical Laboratory'.
The Metallurgist, vol.3, no.2 (March 1964), 30.

From the start, metallurgical work constituted an appreciable, or even substantial, part of the NPL's activities. An assistant-in-charge of metallurgy and chemistry, H.C.H. Carpenter, was appointed in 1902. Although only four years later he moved away on his appointment as professor of metallurgy in Manchester, Carpenter, while at the NPL, was able, with others, to determine for subsequent publication the equilibrium diagrams for the iron-carbon and copper-aluminium alloy systems. The work of the Alloys Research Committee of the Institution of Mechanical Engineers was transferred from the Royal Mint to the NPL soon after 1901 and in the following years significant research results ensued. Work was done on the systematic charting of equilibrium constitutional diagrams for a number of alloy combinations. Carpenter's successor was Dr. Walter Rosenhain, who rapidly gained an international reputation by his researches into metallic problems, including those of alloys of aluminium and magnesium: these came to have timely practical value during the Great War. Useful studies of metal fatigue and creep were also carried out in the laboratory, together with an investigation, in the late 1940s, into aspects of producing titanium metal. The NPL's offshoot, the Chemical Research Laboratory, in 1934 was the source of ion-exchange resins. In subsequent decades these resins were to have considerable use, commercially and for national strategy, in the production of uranium, as well as copper, nickel, and rare metals.⁽⁴²⁾

Throughout the first half of the twentieth century the NPL contributed to metallurgical progress in two ways, one directly for industrial clients, and the other to advance general knowledge and understanding. For industry there were routine testing of products, improvements in practice, and development of modifications and fresh materials; on the broader front the laboratory from its early years followed a deliberate policy of establishing the fundamental properties of metals and alloys, and the data available on them. In the late 1940s, at a time of pressing industrial problems, these practical aspects had precedence, with fundamental research pushed into the background. By contrast, around 1960, roughly two thirds of the work of the metallurgical division was to consist of 'fundamental investigations on subjects relevant to problems of the metal producing and metal-using industries ... chosen to be of wide general interest.'⁽⁴³⁾

(42) APPLETON, Sir Edward, op.cit., 979.

(43) SUTTON, H., op.cit., 31.

With its emphasis on research investigations and work involving precisely controlled measurements the National Physical Laboratory afforded opportunities for training in the appropriate techniques to limited numbers of individuals. Moreover, the published accounts of completed investigations supplied stimulus to research workers elsewhere.

In 1918 the National Physical Laboratory became a part of the Department of Scientific and Industrial Research, set up by the Government as a separate department two years before, during the Great War. The new department was to be widely known as 'DSIR' for a period of some 50 years, up to its incorporation in 1965 in the Science Research Council. Its objects were to bring 'science' into closer contact with industry, and to stimulate national industrial research. The DSIR was put under the control of a Privy Council committee, together with an advisory council whose members represented a fair width of interests; as had happened with the State's previous participation in science at the National Physical Laboratory, the Royal Society was involved. The DSIR council decided that the organisation's activities should cover three main fields:⁽⁴⁴⁾

'firstly, the encouragement of fundamental research at the Universities and the training there of research workers to meet the needs of laboratories of all kinds; secondly, the encouragement of research in industry, particularly through the development of the co-operative spirit ... and, thirdly, the promotion of research to meet the requirements of Government and the needs of the community.'

In its initial year the DSIR was voted a lump sum of £1 million of Government money to spend in fostering industrial research although, in the economic stringencies of the early 1920s, its programme of development had to be curtailed and the future of the organisation was in grave doubt. Much of the £1 million was spent in a strategy by which the DSIR encouraged industrial activity by contributing £1 for each £1 subscribed by commercial groups for co-operative research likely to benefit all the companies in the particular sector. Arising from this provision there came into being a number of industrial research organisations, among them several concerned with metallurgy: the British Non-Ferrous Metals Research Association, the

(44) APPLETON, Sir Edward, op.cit., 974.

British Cast-Iron Research Association, and the British Iron and Steel Research Association. The Copper Development Association was founded in 1933, the corresponding organisation for zinc being set up in 1938, and an equivalent body for aluminium starting after 1940. In 1919 a grant of £1000 was made towards corrosion research. As early as 1920, when the short-lived British Cutlery Research Association was founded under the DSIR scheme, technical developments were planned in collaboration with the University of Sheffield's department of applied science.⁽⁴⁵⁾

In its early years, the chairman of the advisory council of DSIR, Sir William M'Cormick, was also chairman of the University Grants Committee. In 1937 the chairmanship of the DSIR council was filled by Professor L.R. Bragg, professor of physics in the University of Manchester, and known to metallurgists for his work on the structures of metals and alloys: in 1935 Professor Bragg delivered the Institute of Metals May Lecture on 'Atomic arrangement in metals'. During the war of 1939-45 the DSIR's advisory council set up a committee to examine the supply and training of metallurgists and this stimulated similar action on the part of learned societies. Thus, the council of the Iron and Steel Institute stated that it 'welcomes the recent action of the advisory council ... and gladly acknowledges that this action of the department has quickened its interest'.⁽⁴⁶⁾

The department's expenditure on research increased from £330 000 in 1919-20 to $£\frac{3}{4}$ million in 1938-39, and to more than £3 million in 1947-48. By 1960 the sums involved were to multiply again, to more than £10 million.⁽⁴⁷⁾

Besides its activity in stimulating research within industry, the DSIR encouraged post-graduate studies carried out in academic departments in fields which included metallurgy. This was done by making grants for equipment and the support of students and, in the thirty years between 1920 and 1950, it was a significant factor in determining the growth, or even the continuing viability, of all university metallurgy departments. In 1938

(45) SAYERS, R.S., 'The springs of technical progress in Britain, 1919-39'. Econ.Jrnl., vol.60 (June 1950), 280.

(46) COUNCIL OF IRON AND STEEL INSTITUTE, in preface to 'The training of metallurgists with special reference to the iron and steel industries'. Jrnl.Iron Steel Inst., vol.149 (1944), pt.1, 601P.

(47) ARGLES, Michael, South Kensington to Robbins
(London: Longmans, 1964), 132-133.

the amount allocated by DSIR for research training and the advancement of academic work in all subjects was about £26 000; in 1948-49 the corresponding sum totalled nearly £ $\frac{3}{4}$ million.⁽⁴⁸⁾ Metallurgy shared the benefits arising from distribution of these funds. Development of the Ph.D. degree in Britain as the recognised academic qualification for successful post-graduate training in research was due in large measure to the DSIR. This policy received Foreign Office support because of its potential value in attracting research students from overseas.⁽⁴⁹⁾ In 1957-58 the DSIR was to increase the scope of its encouragement for technology and science by supporting regular courses of instruction at post-graduate level as well as research. In this way, around 1960, there were to be provided three kinds of DSIR award for post-graduate work:⁽⁵⁰⁾ 'research studentships' to supply maintenance to those being trained in research methods; 'advanced course studentships' for those pursuing suitable post-graduate courses; and 'research fellowships' for post-doctoral investigators.

Besides the patronage of post-graduate work in academic departments by the DSIR during the period 1920 - 1950, Government granted financial help to universities and university colleges in England and Wales in other ways in the years after 1889. Even before that year, one anomaly in England was that, in the 1870s, the examiners of the University of London received State support to the extent of £1700 a year.⁽⁵¹⁾ The Devonshire Commission in 1874 recommended the making of State grants to the colleges in London and Manchester, but it was not until 1889 that such aid materialised with the first yearly sum of £15 000 voted by the House of Commons for distribution among the English university colleges. In 1897 the amount was increased to £25 000. An interesting and reasonable proviso was that the sum granted to any individual institution was not to exceed one fourth of its local income.⁽⁵²⁾ In the nineteenth century at least, the university colleges in Wales and Scotland fared better than their

(48) APPLETON, Sir Edward, op.cit., 985.

(49) LAYTON, D., 'Education in industrialized societies', in WILLIAMS, T.I. (ed.), A history of technology vol. 6 the twentieth century c.1900 to c.1950, part one. (Oxford: Clarendon Press, 1978), 157.

(50) GOLDSMITH, M., Careers in technology. (Harmondsworth, Middx.: Penguin Books, 1st edn. 1963), 168.

(51) CARDWELL, D.S.L., op.cit., 124.

(52) BALFOUR, Graham, op.cit., 251.

English counterparts: in addition to recurrent grants, during the period 1860 - 1903 the Scottish institutions received almost £ $\frac{1}{4}$ million towards building funds.⁽⁵³⁾

An advisory committee on grants to university colleges was set up in 1904 under the chairmanship of Lord Haldane to help administer the growing sums supplied by the Treasury. In 1911 the grants came under the control of the Board of Education but eight years later, in 1919, Treasury control was restored, with administration effected through the new University Grants Committee. P.W. Musgrave has pointed out that the war of 1914-18, with its attendant shortage of students, led to a crisis in university finances. In November 1918 representatives of the universities were invited to meetings with the chancellor of the exchequer and the president of the Board of Education.⁽⁵⁴⁾ As a result, by a Treasury minute of 14 July 1919, the chancellor announced his intention to appoint a standing committee, the University Grants Committee, 'to enquire into the financial needs of University Education in the United Kingdom and to advise the Government as to the application of any grants that may be made by Parliament towards meeting them.'⁽⁵⁵⁾ At that time, 1919-20, the amount of State aid distributed through this channel was nearly £700 000; ten years later it had doubled to £1 $\frac{1}{2}$ million; ten years later again, in 1940, it had reached £2 million, while in 1945-46 it exceeded £5 million.⁽⁵⁶⁾

The first chairman of the University Grants Committee, the 'UGC', was Sir William S. M'Cormick, who held a similar position in respect of the DSIR, and in 1906 had first served on the committee which preceded the UGC.⁽⁵⁷⁾ Besides administering Treasury funds paid to institutions for higher education, the UGC assumed responsibility for co-ordinating their

(53) BALFOUR, Graham, op.cit., 257; 282-284.

(54) MUSGRAVE, P.W., Technical change the labour force and education. (Oxford, etc.: Pergamon Press, 1967), 183.

(55) UNIVERSITY GRANTS COMMITTEE, Report of the University Grants Committee 3 February 1921. (HMSO, 1921), Cmd. 1163, 2.

(56) ARGLES, Michael, op.cit., 71. However, LAWSON, John and SILVER, Harold, in A social history of education in England, (London: Methuen, 1973), 404, give the figure of over £1 million in 1919-20 for 'treasury grants to British universities'.

(57) SHINN, Christine E., 'The beginnings of the University Grants Committee'. Hist.of Education, vol.9, no. 3 (1980), 234.

development efforts, and came to influence the directions in which developments were made. In the years between 1945 and 1950, according to P.W. Musgrave, the UGC helped to start new post-graduate metallurgical courses in the universities of Sheffield and Birmingham; at Sheffield a school of physical metallurgy was set up, while at Birmingham the available courses were widened into two alternative streams.⁽⁵⁸⁾ Certainly, in the years after 1943 the size of the UGC was enlarged, and its terms of reference broadened and made more explicit. Fourteen years after 1950, responsibility for Parliamentary grants to the universities was to be transferred from the Treasury to the Department of Education and Science.⁽⁵⁹⁾

The last decade of the hundred-year period 1851 - 1950 was in many respects the most active both for metallurgy and for the general growth of technology, including facilities for instruction. In 1945 there was published the Percy Report, Higher technological education, which resulted from an initiative by the minister of education. Shortly afterwards came the findings of another official enquiry, the Barlow Report. This was prepared by a committee appointed by the lord president of the council, Herbert Morrison, one of the three senior ministers in Clement Attlee's post-war Labour Government. In terms of membership the Barlow Committee was a small group half the size of the Percy Committee and it was composed of men who were not primarily politicians but were mainly engineers, technologists, and scientific administrators. Sitting under the chairmanship of Sir Alan Barlow, a Treasury official, its other six members were: Sir Edward Appleton FRS (secretary of the DSIR), Professor P.M.S. Blackett, FRS, Mr. Geoffrey Crowther, Sir Alfred Egerton FRS, Sir George Nelson, and Professor S. Zuckerman FRS. The committee's terms of reference were:⁽⁶⁰⁾

'to consider the policies which should govern the use and development of our scientific manpower and resources during the next ten years, and to submit a report ... to facilitate planning in those fields which are dependent on the use of scientific manpower.'

(58) MUSGRAVE, P.W., op.cit., 200.

(59) DENT, E.C., The educational system of England and Wales. (London: Univ.London Press, 1969), 199-200.

(60) MACLURE, J. Stuart, Educational documents England and Wales 1816 to the present day. (London: Methuen, 3rd edn. 1973), 230.

The Barlow Committee concluded there was need for substantially greater numbers of people trained in the 'pure' sciences to the equivalent of degree level. It recommended the immediate aim should be to double the output of scientific graduates from British universities. However, the committee added the qualification that, in any expansion of places, equal preference should be given to students of humanities as to those of science. Government accepted the Barlow report and, such was the spirit of euphoria at the end of the 1940s, steps were taken to provide for substantial expansion of under-graduate instruction. In the event, the committee's target of 5000 science graduates each year was reached sooner than expected, in 1950. In common with other branches of technological study, metallurgy profited from the policy of expansion. At the same time so, too, did all other subjects, with the consequence that in the 1960s and 1970s engineering, technology and science were to continue to attract some of the weaker students as well as some of the most capable.

In 1947 Government commitment to sponsorship of technology and science was further increased by formation of its Advisory Council on Scientific Policy, whose first chairman was Sir Henry Tizard. In the years following its creation, this council endorsed the view expressed by the Barlow Committee that there was need for more university-trained scientists. Compared with earlier years, around 1950 there was greatly increased desire on the part of politicians to be seen to have some involvement with, and sympathy for, matters technological and scientific. As a result, in the subsequent decades very large sums of public money were to be spent on projects in these fields, as well as on increasing the facilities for relevant instruction, including that in metallurgy. Unfortunately, however, in spite of the Government's sizeable expenditure on 'planning', the match between the demand and supply of trained technologists was to prove poor, as was the balance between academic departments offering advanced tuition in metallurgy and the numbers of suitable students coming forward to occupy the places.

To give effect to the aim of exploiting the mineral riches of the Empire, which was the chief reason why the Government School of Mines opened in London in the year of the Great Exhibition, the 'school of mines' concept was appropriate, and in the succeeding decades it proved its value. However, for promoting the subject of metallurgy in its wider connotations, including the treatment of metals and alloys to yield useful products, the concept was unsuitable because it neglected engineering aspects. Formal instruction in 'engineering' was almost as rare as that in metallurgy in the third quarter of the nineteenth century, although at King's College London a lecturer in 'manufacturing art and machinery' had been appointed in 1839, while at University College London three engineering chairs were founded during the 1840s: in civil engineering, in mechanical engineering, and in machinery.⁽⁶¹⁾ Also in 1840 a chair of engineering had been created in Glasgow, with a professorship in civil engineering following in Manchester in 1868. Interestingly, in the Sheffield Technical School which opened in 1884, there was initially a joint professorship of 'engineering and metallurgy', but when in 1889 the occupant, W.H. Greenwood ARSM, left to return to industry, the post was split into two separate chairs, respectively occupied by William Ripper and J.O. Arnold. There is some evidence that the Prince Consort 'envisaged^{an} engineering college for the whole of the British Empire - in South Kensington - together with its industrial museum and science library as a permanent memorial of the success of the Great Exhibition of 1851'.⁽⁶²⁾

However, like metallurgy, British engineering education proved to be shackled by the conservative notion among employers that students could only learn many of the details of the subject by spending several years performing menial tasks in industrial surroundings. Nonetheless, during the last quarter of the nineteenth century, and continuing in the following decades, formal engineering tuition made strides forward which were large compared with those in metallurgy. In the growth of technological instruction that occurred from the 1880s, the subject of metallurgy was greatly overtaken by engineering, thereby effectively losing substantial ground to the wider

(61) ARMYTAGE, W.H.G., A social history of engineering.

(London: Faber and Faber, 1st edn. 1961), 149-150.

(62) BURSTALL, Aubrey F., A history of mechanical engineering.

(London: Faber and Faber, paperback reprint 1970), 286.

subject; it became common for the mechanical properties of metals to be considered as a portion of the engineering spectrum rather than as part of an expanding metallurgical domain. After 1890 it was not until the closing decade of the century 1851 - 1950 that significant positive steps were taken by Government to identify 'metallurgy' as a subject meriting encouragement in the national interest as something distinct from engineering.

From before 1851 the Committee of Trade had an interest in technical 'education'. Subsequently, increasing national trade pressures, fuelled by comparisons made with the situations and standards in other countries, led to the channelling of public money into technical instruction. In the wake of the Paris Exhibition of 1867 the 1868 Samuelson select committee of the House of Commons had its origins in this concern at adverse commercial effects. In addition to this 1868 select committee on scientific instruction for the industrial classes, during the second half of the nineteenth century, there were made two other important Government enquiries into technical and/or scientific instruction: the Royal Commission on scientific instruction and advancement of the early 1870s, and the Royal Commission on technical instruction of the industrial classes a decade later. The effects of this trio were profound, but for present purposes they are considered as having been achieved through the medium of the education office.

Before 1900 the influence of other official enquiries, such as that into the trade depression of the 1880s, though less important, was also significant. Further concern was shown during the Great War of 1914-18, with 'departmental' committees set up to examine how best technical training might be provided to help the post-war industries. When the post-war period duly arrived, soon followed by a return to depressed trading conditions, more official enquiries were instituted by the Board of Trade and the Ministry of Labour as well as by the Board of Education. A concerted effect of the various enquiries was increased opportunities for general technical education within local junior technical schools and technical colleges. In the 1940s the enquiries and departmental committees were renewed, and in the changed climate that prevailed large sums were voted for higher and other levels of education in all disciplines.

Besides interests in trade and employment, in the Royal Mint Government had a direct stake in non-military metallurgical technology. The State provided encouragement to industries through the Patent Office, the National Physical Laboratory (NPL), and the Department of Scientific and Industrial Research (DSIR). These fostered industrial awareness of technological efficiency. In pursuing their aims the NPL and DSIR created jobs for metallurgists, albeit in small numbers initially, stimulated metallurgical research, and supplied much-needed financial aid to academic metallurgy departments. Indeed, during the 1920s and 1930s Government action taken through the DSIR was a major influence in promoting industrial interest in metallurgy and developing industrial demand for the services of trained metallurgists, as well as for other technologists. This stimulated demand was reflected back into tuition, at any rate at the advanced levels where the same agency, the DSIR, helped departments to provide appropriate instruction. As well as this encouragement through the DSIR, the State influenced the higher levels of metallurgical instruction by Treasury funds which from 1889 were fed into English and Welsh universities and university colleges in increasing amounts. From 1919 the mechanism by which such grants were made was co-ordinated by the University Grants Committee (UGC). Although during the 1920s and 1930s both the UGC and the DSIR were active largely for civil reasons, it has to be remembered that the DSIR was born of the Great War while the same conflict influenced the scale of direct State aid to universities and university colleges and the nature of the UGC.

It is concluded that with the passage from 1851 to 1950 non-military State influence on metallurgical instruction grew in extent. Throughout the century the most important civil stimulus to State aid was the desire to compete successfully with other nations in trade.

CHAPTER 6

GOVERNMENT SUPPORT OF METALLURGY FOR MILITARY REASONS

Even in 1851, although the Great Exhibition in London's Hyde Park was intended to be more of a trade battle than a military one, officers and men of the British army made significant contributions to the occasion. The chief Royal Engineer at Woolwich, Lieut.-Col. William Reid, was appointed chairman of the executive committee for the exhibition, and at one time thirteen Royal Engineer officers and two companies of 'other ranks' were at work on the Hyde Park site.⁽¹⁾ Subsequently, army officers were enrolled to supervise local Science and Art Department examinations, while one officer, Captain Francis Fowke, who had received architectural instruction at Chatham, was responsible for the design of the Victoria and Albert Museum and other public buildings;⁽²⁾ the Albert Hall was completed by another RE officer, Major-General H.Y.D. Scott. In 1859, the Science and Art Department's newly-appointed inspector for science was a serving RE officer, J.F.D. Donnelly.

Between the Battle of Waterloo in 1815 and the onset of the Great War of 1914-18, despite a scare in 1875 Britain was not directly involved in a western-European war for a century;⁽³⁾ nonetheless, the country's military resources were expended in other parts of the world. Within a few years of the 1851 exhibition, British troops were fighting in the Crimean War (1854-56)

(1) BOYD, Derek, The Royal Engineers. (London: Leo Cooper, 1975), 39.
Hereafter referred to as 'Boyd (1975)'.

(2) Boyd (1975), 38.

(3) THOMSON, David, England in the nineteenth century (1815-1914).
(Penguin Books, 1977; 1st publ. 1950), 181.

Further from home, in India, troops were engaged in the situation surrounding the Indian Mutiny of 1857 and, in the North-west Frontier Province, sporadically throughout the latter half of the nineteenth century. The British army was involved with fighting in Abyssinia in 1867, and with trouble in China three years later. In the 1870s military campaigns were mounted in West and South Africa and in Afghanistan. In the 1880s the army took part in fighting in Egypt and the Sudan, and in capturing Mandalay in Burma.

Even if, in the closing years of the century, it appeared there were fewer active demands made of the British soldier than in earlier years, the continuing sums spent at that period on naval facilities indicate that the peace was an uneasy one. The Boer War in South Africa (1899-1902) provided a fresh opportunity for active service, and there were then a dozen years of relative calm before the British found themselves drawn, in August 1914, into what came to be known as the 'Great War', with fighting in France. The end of this terrible phase of slaughter and destitution, in November 1918, was followed by another period of nonactivity and uncertain peace until war was again declared in September 1939. This Second World War was fought on many fronts, and made heavy national demands up to the surrender of Japan in August 1945, which followed that of Italy and Germany a few months earlier. Although the end of fighting then resulted in a great demobilisation of personnel and a corresponding abandonment of all kinds of equipment, British military expenditure remained on a considerable scale, and was to continue thus up to the present time: troops were deployed in Germany in large numbers, as well as in various parts of the world outside Europe. Despite the fact that throughout the first half of the present century the numbers of people employed militarily fluctuated widely from war-time peaks to post-war troughs, the service commanders appear to have maintained some interest in trying to obtain equipment incorporating the latest technological advances.

Metals were used by the army and navy prior to 1851, but the second half of the nineteenth century saw great increases in the quantities involved and in their variety. Only a few years after 1851 a civilian in London, Henry Bessemer, launched his revolutionary process of steelmaking, which was a byproduct of his efforts to make, at French Government request, more powerful

projectiles and guns. Bessemer's invention brought about the beginning, soon after 1860, of the Age of Steel. Even before the new bulk material became widely available, the Admiralty was using iron for ships' engines and, from 1860, for their hulls, HMS Warrior being one of two vessels built in iron on the Thames in that year: before long, wooden-hulled naval vessels were being scrapped as obsolete. Turret-mounted guns, adapted from the USA, were introduced by the Royal Navy. By the turn of the twentieth century the sizes of warships, their steam propulsion engines, and their guns, had all been greatly increased.

One marine destructive weapon was the self-propelled torpedo, driven by compressed air; by 1905 it had been developed to the point where it could be described as 'the first underwater guided missile', such remotely-controlled torpedoes being in British naval use.⁽⁴⁾ 'Submarine' vessels were also part of naval strength, Britain ordering five in 1901 and becoming more-widely committed after 1915.

Ship propulsion gradually changed from reciprocating engines to high-speed rotary turbines; during the twentieth century in place of steam increasing proportions of new naval vessels came to be fitted with internal-combustion engines. Naval forces came to rely increasingly upon metals of various kinds, not least for their communication systems. Use of metal in the marine environment led to serious corrosion problems which required sustained metallurgical effort for their investigation and prevention. After 1950, the adoption of nuclear-powered submarines was to cause studies at the Royal Naval College in Greenwich to include instruction in aspects of the relevant materials in a department of nuclear science and technology.⁽⁵⁾

The hundred years 1851 - 1950 saw the gradual mechanisation of the army, the use of various more-powerful and more-rapidly-firing guns with matching developments in their missiles, and the introduction of the electric telegraph for signalling: all of these involved metallurgy. The line telegraph, and

(4) Boyd (1975), 53.

(5) CARTER, J.H., personal communication, 1978.

Principal Lecturer in Chemistry, Department of Nuclear Science and Technology, Royal Naval College, Greenwich.

later the wireless telegraph, had large impacts on both navy and army. Their adoption brought unavoidable dependence on long lengths of metallic wire, together with other metallic items of equipment, and the need for personnel with ability to join and handle such materials. Hundreds of tonnes of barbed wire were involved in forming barricades.

During the second half of the nineteenth century, the army relied to a large extent upon horses to supplement manpower for transport and freight purposes, but little by little mechanisation took over: in the Abyssinian campaign of 1867 a railway line nearly twenty km long was built close to the Red Sea.⁽⁶⁾ In the mid-1880s a military railway was laid and operated in Egypt,⁽⁷⁾ and a major-general of the Royal Engineers built a strategic line from the Indus to the passes on the North-west Frontier beyond Quetta and into Baluchistan, a distance of 350 km;⁽⁸⁾ another army railway was constructed in the late 1890s during the re-taking of the Sudan. Steam engines were not confined to rails: in the Ashanti War of 1873-74 'the first Steam Sapper traction engine', called Prince Arthur, was used,⁽⁹⁾ while in the Boer War at the turn of the century steam traction engines hauled heavy guns through the South African countryside. In Europe the 'tank', or 'land cruiser' as it was first named, was introduced by the British army into France during the Battle of the Somme in September 1916, marking another important advance in military mechanisation.⁽¹⁰⁾

The army's increasing dependence on wheeled vehicles brought with it the need for bridging facilities: during the 1939-45 war large quantities of steel went into constructing more than 300 km of 'Bailey bridge' segments in the British Isles.⁽¹¹⁾ In the same conflict, the 'Mulberry harbour' enabled dock facilities to be provided on the north-west coast of France, at Arromanches, to support the allied landings in June 1944.

(6) Boyd (1975), 51.

(7) Boyd (1975), 58.

(8) Boyd (1975), 61.

(9) Boyd (1975), 56.

(10) ADDISON, Christopher, Four and a half years.
(London: Hutchinson, 1934), vol.1, 248.

(11) Boyd (1975), 96.

The Great War of 1914-18 saw a new dimension added to military tactics with the use of powered aircraft. As far as Britain was concerned, use of aeroplanes for war purposes was begun by members of the Royal Engineers, and continued as the Royal Naval Air Service during the war, becoming the separate Royal Air Force shortly after the ending^{of}/hostilities. Twenty years later, the demands of the RAF during the war of 1939-45 led to greatly-increased production of metals such as aluminium and magnesium and to development of improved alloys, for example to combine lightness with strength for aircraft bodies. It was in connexion with aerial warfare that 'radar' was developed by the British in time to be of vital significance in 1940: the equipment depended upon metallurgical skills as well as upon non-metallic materials, notably the timely new 'polythene' with its outstanding insulating properties at high frequencies.

Finally, atomic energy entered the scene in 1940. For military purposes this was based on the metallic elements uranium and plutonium, and the successful British production and harnessing of atomic energy after 1945 represented the solution of large numbers of metallurgical problems.

State financial participation in aeronautics can be traced from 1878, when the War Office agreed to allocate £150 for construction of a balloon at Woolwich Arsenal, for use by an army group. In 1890 an air estimate of £4300 was voted; fifteen years later experiments were begun with a glider,⁽¹²⁾ and because of the prospective defence interest in aviation, at Farnborough near Aldershot in Hampshire, there was formed 'what was to become the Royal Aircraft Establishment' (RAE).⁽¹³⁾ In the following years, despite War Office discouragements, the Farnborough establishment developed into an aeroplane factory, although at least until after 1920 it also retained responsibility for kites, balloons, and dirigibles. In 1916 a War Office committee decreed that Farnborough should concentrate on research and development rather than carry out production, and soon afterwards knowledge

(12) WALKER, J. Stubbs, 'The Royal Aircraft Establishment'.
Discovery, vol.8, issue 9 (1947), 279-280.

(13) JONES, R.V., 'Research Establishments'.
Proc.Royal Soc. Lond.A, vol.342, (1975), 481.

was being sought concerning the behaviour of metals used in aircraft and their performance under the loading conditions likely to be encountered in service.⁽¹⁴⁾ Around 1920 the Air Ministry was created, while in 1924 its director of scientific research was appointed. In the 1920s the metallurgical superintendent of the Research Department at Woolwich Arsenal served on two sub-committees of the Aeronautical Research Committee. As he later recalled,⁽¹⁵⁾

'this brought me into close touch with the fruitful work on steel and light alloys at the National Physical Laboratory, Farnborough and elsewhere: Very interesting developments were taking place in research on fatigue, creep and strength problems generally ... '

However, throughout the decade of the 'twenties, and up to 1935, the level of expenditure authorised for the RAE was small. In 1937 the autumn lecture to members of the Institute of Metals, meeting in Sheffield, was given by the deputy-director of scientific research at the Air Ministry, Dr. D.R. Pye, FRS, on 'Metallurgy and the aero-engine'.

Subsequently, the work done on metallic materials played a vital role both in the successful prosecution of the war of 1939-45 and in the technological developments which followed it, such as the turbine and jet engines for aircraft, and the exploitation of atomic energy. A 1946 account of the metallurgical division of the RAE described its activities as falling into four categories: examination of service failures and manufacturing defects; assessment of industrial methods, processes and materials; research into improvements of processes and materials; and fundamental research into the principles underlying the mechanical behaviour of metals.⁽¹⁶⁾ Work on corrosion, particularly that of stressed components, was important, and the metallurgical division was responsible for extensive long-term investigations into metal creep and fatigue, and for work on the theory of strength of

(14) WALKER, J. Stubbs, op.cit., 281-282.

(15) MOORE, Harold, 'Some recollections' (part 2),
The Metallurgist, vol. 1, no.2 (Mar. 1960), 74.

(16) ANON., 'Metallurgy at the Royal Aircraft Establishment',
Engineering, vol.161, pt. 4182 (8 Mar. 1946), 236.

brittle solids. The comment was made that the laboratories 'have afforded an excellent practical training to a number of young university graduates, which ... would make them well fitted to take their place in industry.'⁽¹⁷⁾ Among the new materials which seemed to show promise was titanium: 'ductile titanium was first made in quantity in the UK at RAE ... and the ... apparatus was subsequently scaled-up in industry ... for alloy development in 1947.' In the early 1960s, the RAE at Farnborough was to be 'the largest Government research and development establishment in this country'.⁽¹⁸⁾

Of the scientific and technological advances which were put to practical use during the war of 1939-45, one of the most innovative was the 'atom bomb': two such bombs dropped on unfortunate Japanese cities on 6 and 9 August 1945 effectively brought a rapid end to hostilities, with the acceptance of surrender. The idea of the feasibility of using nuclear energy as a new form of explosive for military purposes followed the many rumours of 'death rays' which, during the 1930s, were claimed from a series of sources. Physicists in Britain in 1940 succeeded in impressing Government with the potentialities of a uranium bomb; originally handled by the Committee for the Scientific Survey of Air Warfare of which Sir Henry Tizard was chairman, from mid-1940 work associated with the project was made the responsibility of a separate sub-committee within the Ministry of Aircraft Production: the M.A.U.D. Committee.⁽¹⁹⁾ By the end of 1940 uranium metal, as well as some compounds, were being made at Birmingham University and by I.C.I. Ltd.⁽²⁰⁾ A few months later, in conjunction with experimental work carried out in the USA, the practicability of a bomb was proved. In the middle of 1941 the M.A.U.D. Committee produced two reports, one on the 'use of uranium for a bomb', and the other on the 'use of uranium as a source of power';⁽²¹⁾ in September 1941 the British chiefs of staff and prime

(17) ANON., loc. cit.

(18) NORTHCOTT, L., 'Presidential address - metallurgy and the civil service'. The Metallurgist, vol. 2, no.10 (July 1963), 233.

(19) GOWING, Margaret, Britain and atomic energy 1939-1945. (London: Macmillan, 1964), 378.

(20) GOWING, M., op.cit., 63.

(21) GOWING, M., op.cit., 394 and 427, reproducing the texts of the reports, pp.394-426, and pp. 427-436.

minister, Winston S. Churchill, agreed that the project should be developed with all possible vigour.

Up to this stage the British atomic-bomb work seems to have involved top-level physicists and chemists, but hardly any metallurgists. Moreover, from this stage, work with similar aims done in the USA for the US Government was on a much greater scale, so that British participation in the programme which led to the dropping of the two atomic bombs on Japan in 1945 was marginal rather than central. In Britain the small numbers of competent technological and scientific graduates available for all the manifold duties demanding their attention became all too apparent. When a joint Canadian-British team was established in Montreal at the end of 1942 to carry out further work on atomic energy, the leading scientists appointed to it were an international collection, nearly all non-British. I.C.I. seconded three engineers and one metallurgist.⁽²²⁾

Uranium metal production on the modest scale of nearly half a tonne a week was pursued by I.C.I. in Britain in 1943 and 1944, during which time many difficulties associated with processing were overcome so that extensive knowledge was obtained of problems involved in larger-scale working.⁽²³⁾ The British decided that, whatever might be the state of post-war collaboration with Canada and the USA, atomic-energy development should be continued on UK soil. Towards this end, by the spring of 1945 the British Government authorised a start to be made on the experimental station for atomic energy which was to grow up at Harwell during subsequent years. As prime minister Clement Attlee announced in the House of Commons in January 1946, a Division of Atomic Energy Production was created 'to make available as speedily as possible material in sufficient quantity to enable us to take advantage rapidly of technical developments as they occur'.⁽²⁴⁾ Responsibility for the work was transferred from the Department of Scientific and Industrial Research to the Ministry of Supply. Within the next few years there

(22) GOWING, M., op.cit., 191.

(23) GOWING, M., op.cit., 337-338.

(24) JAY, K.E.B., Britain's atomic factories the story of atomic energy in Britain. (London: HMSO, 1954), 5.

developed at the Ministry of Supply's Springfield Works near Preston a plant for producing uranium metal and hexafluoride in tonnage quantities, at the Cumbrian Windscale Works a plant for separating plutonium from irradiated uranium, and at Capenhurst the necessary large-scale equipment for separating highly-enriched uranium-235 isotope from the naturally-occurring mixture. At Windscale also, as an essential step in preparing the synthetic element plutonium, there was built 'the world's first peace-time industrial atomic pile', producing useful energy from atomic reactions proceeding at controlled rate. As had been the case before 1945, in the post-war period some of the early production of uranium metal and hexafluoride was carried out by I.C.I. at Government request.⁽²⁵⁾

The object of the British programme from 1945 was two-fold: to yield atomic bombs with obvious military applications, and to develop the enormous peaceful potential of atomic energy, both lines of progress foreshadowed by the M.A.U.D. reports of 1940. The wisdom of the decision in 1945 to resume development of atomic energy within Britain appeared well vindicated the following year when, in the USA, Congress passed the McMahon Act which severely curtailed possibilities for collaboration on many aspects of the work.⁽²⁶⁾ By 1958 the staff employed by the Atomic Energy Authority was to total 25 000.⁽²⁷⁾ It is clear that the new industry demanded considerable numbers of metallurgists, together with other technologists and engineers. The high national priority accorded to the atomic-energy programme meant that during the years around 1950 Government made substantial inducements to academic departments to provide trained people in suitably-large numbers. There is no doubt this was one of the most potent factors contributing to the great extension of opportunities for metallurgical instruction which took place after 1945 and was to be sustained during the decade of the 1950s. Likewise, the job opportunities within the British atomic-energy industry created considerable demand for those possessing formal metallurgical training and thereby stimulated interest in such training.

(25) JAY, K.E.B., op.cit., 7.

(26) JAY, K.E.B., op.cit., 4.

(27) DENT, H.C. (ed.), The year book of technical education and careers in industry 1958. (London: A & C Black, no date), 780.

The two European wars in the first half of the twentieth century gave rise to State interest in raw-material resources. For example, during the 1914-18 war a Government agency was formed to control British iron-and-steel production and to ensure the procurement of all supplies necessary to yield the quantities and grades of steel wanted to sustain the war effort. One strategic component of tool steels was the metal tungsten, which prior to 1914 was virtually all controlled by Germany which had established a world monopoly for processing ores; the outbreak of war necessitated manufacture of tungsten in Britain. A second use for tungsten which became important was in balancing the crankshafts of aeroengines, where its high density was an advantage.⁽²⁸⁾ Accordingly, a 'tin and tungsten research committee' was set up, its investigations being done partly in academic departments; for instance, a lecturer at the Royal School of Mines carried out treatment tests on Cornish tin ores.⁽²⁹⁾ The treasury paid for the publication of a series of reports, prepared by the Geological Survey, on British mineral resources. Volume one, on Tungsten and manganese ores, first appeared in 1915 with volume two, on Barytes and witherite, closely following, while volume four, Fluorspar, came out in 1916. Altogether, more than twenty separate reports were compiled, on materials which included refractories, iron ores, lead, zinc, and copper minerals.

The Ministry of Munitions, encouraged by the main metallurgical institutions, sponsored the development of mineral resources. In March 1917 it created a new section to develop home minerals, while in the following month wider proposals were submitted by the minister, Dr. C. Addison, to the Imperial War Conference. These proposals were intended to encompass the whole empire by means of:⁽³⁰⁾

'An Imperial Mineral Resources Commission to conduct surveys and to advise on the best means of developing the Empire's ... resources, and ...

The establishment of working corporations - British and Dominion - for promoting development.'

(28) SMITHELLS, Colin, J., 'Reminiscences, Eheu Fugaces'.

The Metallurgist, vol. 2, no. 6 (Nov. 1962), 145.

(29) YATES, A., 'Effects of heating, and heating and quenching Cornish tin ores before crushing'. Trans.Instn.Mining Metall., vol.28 (1918-19), 41-43.

(30) ADDISON, Christopher, op.cit., vol. 2, 344; 371.

As the minister explained, the object was to devise a plan whereby mineral resources might first be ascertained, and then developed and exploited to meet market requirements, by an organisation free from alien control. Consequently, an Imperial Mineral Resources Bureau was brought into being, with duties to 'collect and disseminate information as to resources, production, treatment, consumption and requirements of every mineral and metal of economic value', as well as to advise on the development of imperial mineral resources. The British representatives on the bureau's governing body included Professor H.C.H. Carpenter of the Royal School of Mines, who was president of the Institute of Metals, and two ex-presidents of the Institution of Mining and Metallurgy.⁽³¹⁾ The scheme envisaged, however, did not obtain unqualified support when it was discussed at the Imperial Conference in July 1918,⁽³²⁾ and in the subsequent lean economic climate British Government financial support for development was limited.

To some extent, the pattern of 1914-18 was repeated during the 1939-45 war, with investigations made at Government expense into mineral deposits in various parts of the country: for example, tests were made of the feasibility of extracting fluorspar from accumulated dumps of tailings at old mines in the northern Pennines, and surveys were undertaken to assess the domestic potentialities for lead, zinc, and fluorspar mining. During the 1950s and 1960s the Government war-time reports on British mineral resources were to constitute the useful basis for all further work done, both academically and commercially.

At the conclusion of hostilities in Europe in 1944, large numbers of skilled people were sent by the British Government to appraise and report on aspects of German industry: metallurgists were among the experts who took part in this campaign. Subsequently, many of the reports of the British Intelligence Objective Sub-Committee (BIOS) became available to readers in Britain. For instance, BIOS Overall Report No. 15, entitled 'The ferrous metal industry in Germany during the period 1939-1945', was written by George Patchin and Ernest Brewin. George Patchin, ARSM, was principal of the Sir

(31) ADDISON, Christopher, op.cit., vol.2, 531.

(32) ADDISON, Christopher, op.cit., vol.2, 549-550.

John Cass Institute in London from 1926 to 1945, and also head of its metallurgy department.

Sponsorship, for military purposes, of research and new developments in materials has been on a substantial scale since the 1940s, but it also took place to a smaller extent throughout the previous 70 or 80 years. Henry Bessemer claimed that while he was first developing his new steel-converting technique in the years around 1860, the commandant of the Royal Arsenal at Woolwich, Col. Eardley Wilmot, showed great interest in the work and had experiments made with the new material; similarly, the Royal Navy's chief shipbuilder tried Bessemer steel for ships' parts only a few years later. At that time the new material was more costly than its equivalent in wrought iron, and interest in it lapsed until at the end of the 1870s there came a revival which, during subsequent years, was to lead to steel's gradually replacing iron for many naval purposes.

Members of the Iron and Steel Institute visited the Woolwich ordnance factory c.1880, and for the occasion the superintendent at the time, Colonel Maitland, together with some of his civilian staff, produced descriptive articles on metallurgical operations carried out within the factory. Ten years later, Dr. Anderson, who was then director-general of ordnance factories at Woolwich and a vice-president of the Institution of Mechanical Engineers, recommended the setting up by that institution of an Alloys Research Committee to investigate the effects of small proportions of impurities on the mechanical properties of metals.⁽³³⁾ During the last decade of the nineteenth century useful work was done and results published, even though the researchers involved were only a handful; the numbers were very small by comparison with the teams of investigators half a century later who were engaged to work on problems with similar military significance. Shortly after 1900, when the new National Physical Laboratory(NPL) opened, experimental work for the programme of alloys' research was transferred to it, and throughout the following years, perhaps particularly during wartime, State-supported research at the NPL contributed to national efficiency and to the introduction of improved materials for military purposes.

(33) SMITH, S.W., Roberts-Austen a record of his work.
(London: Griffin, 1914), 132.

In 1900 an Explosives Committee was created, with Lord Rayleigh as president and Sir W.C. Roberts-Austen a member: Roberts-Austen was professor of metallurgy at the Royal School of Mines and also assay master of the Royal Mint. At Woolwich, a superintendent of chemical research was appointed in 1902, and two years afterwards a metallurgist was included on his staff.⁽³⁴⁾ This man later recorded how 'neither in the Department (of Chemical Research) nor elsewhere were there any definite ideas, apart from my own, as to the subjects on which metallurgical research was needed'. In 1906 Woolwich Arsenal was transferred from civilian control to military; the Explosives Committee was dissolved, and the Research Department henceforward reported to both the Admiralty and the War Office through its chief superintendent, alternately naval and military senior officers.⁽³⁵⁾ By 1910 the Admiralty and the War Office, through their joint Ordnance Committee, had come to recognise the potential scope and value of metallurgical research for service purposes; as a consequence, increasing numbers of problems were referred to the Woolwich Research Department for advice, and the civilian metallurgical superintendent was enabled to engage three or four assistants. In the same year, this metallurgist took part in a British military visit to Swedish steel works, made to judge their importance in the event of war.⁽³⁶⁾ Soon afterwards, because of the realisation of war, the metallurgical staff of the Woolwich Research Department was inundated with work, ranging from examination of 'small-arms ammunition offered by American manufacturers', and 'defects and failures in war material', to helping to devise improved production methods: by the end of the war in 1918, the staff numbered forty, though this was reduced substantially the following year.⁽³⁷⁾

During the 1914-18 war, a committee of the Ordnance Board met each week to consider metallurgical questions: the civilian members were H. Moore from Woolwich, F.W. Harbord, ARSM, from the Ministry of Munitions, N.P.P. Sandberg, a member of a family firm advising the Ministry of Munitions on shell steels, and Sir Alexander Kennedy, former professor of engineering at University College London.⁽³⁸⁾ When the war was over, metallurgical work was

(34) MOORE, Harold, op.cit., 71.

(35) MOORE, Harold, op.cit., 72.

(36) MOORE, Harold, op.cit., 72.

(37) MOORE, Harold, op.cit., 75.

(38) MOORE, Harold, op.cit., 76.

continued at Woolwich, even if on a reduced scale. Publication of results was permitted, members of staff contributed to metallurgical meetings, and they took part in various civilian committees set up to enhance understanding of such things as steel castings and corrosion, having significant economic applications.

Among topics of metallurgical research successfully pursued in the Woolwich Research Department in the years after 1920 were: prevention of failure by 'season cracking' in brass ammunition and condenser tubes; elimination of 'extrusion defect'; production of sound ingots cast in cartridge brass; improved steels for armaments; electrodeposition as a means of reclaiming worn components such as the linings of gun barrels; and substitution of alternative materials for those in short supply. By 1950 the 'Woolwich' work had mostly been transferred to the Royal Armament Research and Development Establishment at Fort Halstead near Sevenoaks, where it was continued on a substantial scale. Dr. (later Sir) William Penney headed the establishment at that time, and formidable metallurgical problems were encountered and resolved in the development of the British atomic bomb. Besides the extensive work done at Fort Halstead, in later years the selection and performance of metallic materials was studied at two army centres: the Fighting Vehicles Research and Development Establishment at Chobham, and the Military Engineering Establishment at Christchurch.⁽³⁹⁾

The British Government's Board of Invention and Research, which was active from July 1915 to July 1917, included on its consulting panel of twelve 'scientific experts' a metallurgist, Professor H.C.H. Carpenter of the Royal School of Mines.⁽⁴⁰⁾ The Board was intended to work closely with the Admiralty on matters involving 'scientific' effort, as well as to assess the value of schemes and suggestions put forward by the public. Professor Carpenter became occupied in an investigation of the Seaplane Sub-committee regarding the possibility of producing non-corrosive metal fittings by treating aluminium 'to form a hard coat of metallic oxides'.⁽⁴¹⁾ The Admiralty set

(39) NORTHCOTT, L., op.cit., 232-233.

(40) MACLEOD, R.M. and ANDREWS, E.K., 'Scientific advice in the war at sea 1915-1917: the Board of Invention and Research'.
Jrnl.Contmp.Hist., vol.6, no.2 (1971), 10.

(41) MACLEOD, R.M. and ANDREWS, E.K., op.cit., 17.

up its Directorate of Scientific Research after the war had ended, in 1921, and an Admiralty Research Laboratory was established alongside the existing NPL at Teddington.⁽⁴²⁾ In 1944 there came reorganisation, with the creation of the Royal Naval Scientific Service (RNSS) to help ensure 'the permanent provision for the Navy of the service which it needs in the fields of research, experimental design and development'; one of the four research departments was concerned with engineering and materials.⁽⁴³⁾

At one time or another, Admiralty research proceeded over a wide spectrum. On the one hand there was a continuing desire to improve the strength of naval vessels without adding to their weight. Then the introduction of welding, partly in response to the destructive effects of gunfire on riveted joints, caused its own difficulties. Sea-water conditions posed corrosion problems which were answered by development of fresh non-ferrous alloys. Ship propulsion also presented features, extending over many years, which called for improvements and modifications. Development of under-water weapons and military electronic devices demanded the attention of metallurgists, as did the application of nuclear propulsion to naval vessels. In 1948 the Admiralty Materials Laboratory was set up to undertake work of a long-term nature, such as investigation of the creep and fatigue behaviour of various materials.⁽⁴⁴⁾

While the foundation of the National Physical Laboratory in the opening years of the century was not primarily for military purposes, or closely associated with war, the formation of the Department of Scientific and Industrial Research in 1915-16 was considerably influenced by the prevailing war-time situation and the inadequacy it revealed. It was early in 1915 that members of the war-time government proposed a two-pronged long-term scheme to remedy the worst aspects of the technological and scientific insufficiency in which the country found itself. One prong of the proposed scheme aimed to improve academic instruction at all levels ranging from secondary schools, through technical schools, to universities, while the

(42) JONES, R.V., op.cit., 482.

(43) DENT, H.C.(ed.), op.cit., 692.

(44) NORTHCOTT, L., op.cit., 234.

other was 'directed to the promotion of research work into industrial and commercial problems'.⁽⁴⁵⁾ In July of 1915 the privy council's Committee for Scientific and Industrial Research was instituted, with an advisory council of seven fellows of the Royal Society under the administrative chairmanship of Sir W.S. M'Cormick. At first it was the intention that the new body should work within the Board of Education, but at the end of the next year, 1916, the new Department of Scientific and Industrial Research (DSIR) became established as a separate entity under the privy council. In its first year or two, the advisory council gave support to twenty projects, and the technical bodies associated with these projects included the Institute of Metals, the Institution of Mining and Metallurgy, and the Iron and Steel Institute, as well as the Institution of Mechanical Engineers and the Faraday Society. Among the topics studied were 'the properties and composition of alloys, the corrosion of non-ferrous metals, (and) tin and tungsten'.⁽⁴⁶⁾ In December 1915 the advisory council formed several specialised standing committees, that on metallurgy including a number of prominent practising metallurgists, Table 6.1.

Three years later responsibility for the NPL, with its metallurgical division, was assumed by the DSIR; in 1920 a Chemistry Research Coordinating Board was created, and in the following few years a Chemical Research Laboratory was established on a site adjacent to that occupied by the NPL at Bushey Park.⁽⁴⁷⁾ During the 1940s the Chemical Laboratory was called upon to participate in separation and isolation of some of the metals required for the national development of atomic energy.

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- (45) ADDISON, Christopher, op.cit., vol.1, 291-295; section headed 'Proposals for a national scheme of advanced instruction and research in science, technology and commerce, and for the establishment of a council of scientific and industrial research'
- (46) VARCOE, Ian, 'Scientists, government and organised research in Great Britain 1914-16: the early history of the DSIR'. Minerva, vol.8, no.2 (1970), 210.
- (47) HUTCHINSON, Eric, 'Scientists as an inferior class: the early years of the DSIR'. Minerva, vol.8, no.3 (1970), 406.

Table 6.1. The DSIR standing committee on metallurgy, 1916

Name of Member	Affiliation
Sir Gerard Muntz (chairman of the committee and of the non-ferrous section)	Institute of Metals
Sir Robert Hadfield (chairman of the ferrous section)	Iron and Steel Institute
Professor J.O. Arnold	Sheffield Society of Engineers and Metallurgists
Sir William Beardmore	
Mr. Arthur Balfour	
Professor H C.H. Carpenter	
Mr. C.H. Desch	West of Scotland Iron and Steel Institute
Mr. F.W. Harbord	Institution of Mining and Metallurgy
Mr. J. Rossiter Hoyle	
Professor A.K. Huntington	Institute of Metals
Mr. W. Murray Morrison	
Mr. George Ritchie	Cleveland Institution of Engineers
Mr. J.E. Stead	Iron and Steel Institute
Mr. H.L. Sulman	Institution of Mining and Metallurgy
Mr. Frederick Tomlinson	

VARCOE, Ian, 'Scientists, government and organised research in Great Britain 1914-16: the early history of the DSIR'. Minerva, vol.8, no. 2 (1970), 210.

The foregoing sections of this chapter have reviewed evidence for the vital part taken by metals in the successful prosecution of military endeavours, and for the way in which knowledge of metals became accepted as a worthwhile sector of military expenditure. As the period 1851 - 1950 progressed, so metallic materials grew in military significance. This fact serves to emphasise the State's need to provide, as part of national strategy, facilities for appropriate instruction.

In 1851 there existed for both army and navy separate training establishments where some technology was taught, though none was concerned specifically with materials. For the army, the Royal Military Academy at Woolwich, founded in the eighteenth century, afforded a means of entry for youths intending to become officers in the Artillery and Engineers. Even before 1851, chemistry lecturers were appointed to its staff, Professor Michael Faraday being in charge of that section from 1829 to 1858 and having an assistant.⁽⁴⁸⁾ According to one source, in 1857 there was also a lecturer in 'practical mechanics, machinery, and metallurgy'.⁽⁴⁹⁾

Arising from the disturbing British incompetence shown during the Crimean War, the secretary of state for war, Lord Panmure, in 1856 appointed a commission to reorganise the instruction given to army officers, particularly those involved with 'science', which in the context can be taken to be engineering and artillery. As a result, the opportunities to study at Woolwich Academy and Sandhurst were opened to public competition, and a Council of Military Education was instituted. At the same time, the long-established Board of Ordnance was abolished, the Royal Artillery and Royal Engineers which it had controlled being transferred to the responsibility of the commander-in-chief.⁽⁵⁰⁾ Ten years later, in 1867, public expenditure on

(48) GUGGISBERG, Captain F.G., 'The shop' the story of the Royal Military Academy. (London: Cassell and Co., 1900), 263.

(49) BARNARD, Henry, Military schools and courses of instruction in the science and art of war. (New York: Greenwood Press, 1969; orig. publ. New York, E. Steiger, 1872), 525-526; quoting Blackwood's Mag., (Nov. 1858).

(50) Boyd (1975), 44.

the Royal Military Academy at Woolwich was £36 000. The staff of about fifteen included a professor of chemistry, C.L. Bloxam, who had earlier been a student at the Royal College of Chemistry in Oxford Street, and who contributed textbooks to the metallurgical-chemical literature of the period. In 1871 the Parliamentary estimates included £140 000 for military education, amounting to about one per cent. of the army vote.⁽⁵¹⁾ It can be inferred that at Woolwich the properties of metals, and their practical applications, formed only a small and even incidental part of the instruction given to cadets, while at Sandhurst both the junior cadet college and the senior staff college were less concerned with such topics.

Of greater direct relevance was the Advanced Class of Artillery Officers, formed at Woolwich Academy in 1864. Its aim was to provide high-level instruction for officers who had completed at least six years' service and who might, at some future time, be put in charge of military factories such as the Royal Gun Factory, or Arsenal, at Woolwich itself. In 1868-69, six attended the two-year course. The 'chemistry' syllabus included the 'metallurgic chemistry of iron', as well as the 'chemical principles of the manufacture and explosion of gunpowder'.⁽⁵²⁾ At the inception of the Advanced Class, Dr. John Percy, in charge of metallurgy at the Royal School of Mines, was appointed its lecturer on metallurgy, and he retained the post until shortly before his death twenty-five years later. In 1861 Percy served as a member of the secretary for war's commission on the application of iron for defensive purposes. The two-year course for the artillery officers included metallurgy in each year, a notice of c.1870 stating:⁽⁵³⁾

In connection with the instruction in metallurgy, the class visit each year some of the principal private establishments in England and Wales, accompanied by Dr. Percy, FRS, the lecturer on this subject ...

The following processes are noted in the Royal Gun Factories: metallurgy of copper, tin, zinc, and their compounds; mechanical and chemical properties of gun metal. Metallurgy of iron ... steel and alloys ... Principles of construction

(51) BARNARD, Henry, op.cit., 522.

(52) BARNARD, Henry, op.cit., 614.

(53) BARNARD, Henry, op.cit., 614-615.

'of cast guns ... of built-up guns, welding, etc.

The steam hammer. Turning, boring, rifling ... '

In 1889 John Percy was succeeded as metallurgy lecturer to the Royal Artillery College by a former student at the School of Mines, Hilary Bauerman, ARSM, who was examiner in mining for the Science and Art Department. Bauerman resigned in 1906, but during the Great War the metallurgical association with the Royal School of Mines continued, although the instruction was given within the school's department of metallurgy in South Kensington. Not only was 'metallurgy' recognised as one of the branches of study in the Advanced Class, but metallurgical laboratories were eventually installed in the Red Barracks at Woolwich, 'and the subject gradually became amalgamated in chemistry and shared in its development'.⁽⁵⁴⁾ The Royal Military Academy itself closed with the advent of war in 1939, and the Military College of Science, as the Royal Artillery College had become in 1921, was dispersed. However, by 1950 advanced technical instruction for the army, in continuance of that formerly provided at Woolwich, was established at the Royal Military College of Science at Shrivenham in Wiltshire, where students were prepared for London external B.Sc. degrees in engineering. A department of chemistry and metallurgy included qualified metallurgists headed by an associate professor.

As far as the Royal Navy was concerned, in 1851 a naval college for commissioned officers was in existence at Portsmouth.⁽⁵⁵⁾ Formal instruction was supplemented by encouraging officers to study at Woolwich or Portsmouth dockyards.⁽⁵⁶⁾ There were in addition, from 1843, dockyard schools for the general instruction of apprentices in the yards: in 1859, at the five schools, 461 apprentices were enrolled together with 599 'factory boys' who attended mainly in the evenings. With the aim of 'securing a body of educated and skilful engineers', the Admiralty's efforts were concentrated in the schools at Portsmouth, Devonport and Sheerness.⁽⁵⁷⁾

(54) JOCELYN, J.R.J. HOGG, O.F.G. and CADDY, J.A., Some notes on the history of the advanced class 1866 - 1939.

(London: General Meeting of Advanced Class Dinner Club, no date, c.1955), 13.

Copy kindly provided by Dr. A.E.W. Smith, 1981.

(55) NICHOL, Rupert and YORK, Alan, RNEC 1880 - 1980 (Royal Naval Engineering College). (Plymouth: Thunderer Publns., 1980), 4.
Copy kindly provided by Commander G.C. George, RN, 1981.

(56) BARNARD, Henry, op.cit., 629-630.

(57) BARNARD, Henry, op.cit., 636-637; 654.

Another relevant development, which took place in 1864, was the opening in South Kensington of a Royal School of Naval Architecture and Marine Engineering, sponsored jointly by the Admiralty and the Institution of Naval Architecture.⁽⁵⁸⁾ To house this school there was erected one of the first buildings on the new 'South Kensington' site, situated on the east side of Exhibition Road. When after less than ten years' occupation, in 1873 the School of Naval Architecture removed to Greenwich, where it was joined by the old Royal Naval Academy from Portsmouth, the vacant building became the home of the science classes transferred from the Museum of Practical Geology in London's West End. Consequently it became known as 'the Huxley Building'. At first, a three-year course was offered by the School of Naval Architecture, but this was extended to four years in 1868. The subjects studied included 'chemistry and metals' in the first year, and 'strength of materials' in the second. Successful students were awarded diplomas of Associateship or, at a higher grade involving independent work in design, Fellowship. In 1869 fifteen engineers and fifteen shipwrights, comprising three quarters of the forty students at the school, were sponsored by the Admiralty. In the 1870-71 session thirty-two students entered the Royal School of Naval Architecture from dockyard schools.⁽⁵⁹⁾ Two students who won Admiralty appointments to the Royal School of Naval Architecture in its opening year had been apprentices in the Devonport dockyard. One subsequently progressed to become director of naval construction: Sir William Henry White, KCB, FRS, who, some time after his retirement in 1902, was elected president of the Institute of Metals.

By 1926 there were four dockyard schools for apprentices, at Portsmouth, Devonport, Chatham and Sheerness. In the upper school, 'heat and metallurgy' were among the half-dozen subjects of both second and fourth years. It was stated,⁽⁶⁰⁾ that all

'higher technical posts in the ... Dockyards ... and in the Naval Construction Department at the Admiralty, are filled by members of the Royal Corps of Naval Constructors ... recruited mainly from Dockyard Apprentices, who ... have been awarded

(58) ROBERTSON, Paul L., 'Technical education in the British shipbuilding and marine engineering industries, 1863-1914'. Econ.Hist.Rev., vol. 27 (1974), 230.

(59) BARNARD, Henry, op.cit., 653-654.

(60) COMMITTEE ON INDUSTRY AND TRADE, Factors in industrial and commercial efficiency (London: HMSO, 1927), 152-153.

'Admiralty scholarships tenable at the Royal Naval College, Greenwich ... '

Until after 1950 the Royal Corps of Naval Constructors, which came into being in 1883 and had responsibility for the 'design, construction and repairs made to HM ships' continued to obtain its recruits from those who had spent two or three years at the Royal Naval College in Greenwich.⁽⁶¹⁾ In the 1930s, the staff of Greenwich Royal Naval College included a professor of chemistry and metallurgy, Dr. Brame, known widely for his textbook on 'fuel', while in 1955 Dr. A.G. Dowson was to be appointed professor of metallurgy.⁽⁶²⁾ However, subsequently much of the work of the former department of chemistry and materials under Professor Dowson was to be transferred to the Royal Naval Engineering College at Manadon near Plymouth;⁽⁶³⁾ this establishment grew gradually from the 1940s, augmenting and later incorporating the RN Engineering College at Keyham which had previously provided specialist engineering courses for the navy. Instruction in 'materials' was to continue to contribute significantly to the courses.⁽⁶⁴⁾

Allied to the British naval and military academies in the later decades of the nineteenth century by the growing needs of superintending an empire, was the Royal Indian Engineering College, established in 1871-72 by the secretary of state and members of the Council of India despite opposition from the handful of existing institutions for engineering instruction.⁽⁶⁵⁾ Situated at Coopers Hill at Englefield Green close to the Thames, where property was bought for £55 000, the object of the new institution was to provide well-trained engineers for Indian services, by a three-year course. In 1906 however, after an active life of only some thirty years, the college closed, its demise being due to several factors which included high cost, changing demand, and growth of other appropriate engineering courses.⁽⁶⁶⁾

(61) DENT, H.C. (ed.), op.cit., 691.

(62) Bull.Instn.Metallurgists, vol.5, no. 6 (May 1955), 20.

(63) CARTER, J.H., personal communication, 1978.

(64) GEORGE, Commander G.C., RN, personal communication, 1981.
HOD Engineering Materials, Royal Naval Engineering College,
Manadon, Plymouth.

(65) ARMYTAGE, W.H.G., A social history of engineering.
(London: Faber and Faber, 3rd edn. 1970), 235.

(66) CAMERON, J.G.P., A short history of the Royal Indian Engineering College, Coopers Hill. (Coopers Hill, near Staines: Coopers Hill Soc., 1960), 17.

Compared with naval and military experiences, aeronautics arrived on the scene only at a late stage. In conjunction with the Royal Aircraft Establishment, at Farnborough a technical college was founded in 1918 'to train young men and women for employment as aeronautical engineers and technologists', but evidently it was not at that time successful, for it was 're-constituted' in 1944. At Farnborough in the late 1950s, five-year day courses 'sponsored by the Ministry of Supply' were to lead students to the academic qualification of London external B.Sc.(Eng.). At that time there were to be on the staff eleven 'chief lecturers' but, to judge by the titles of their posts, none was primarily concerned with metallurgy. It seems probable metallurgy would be dealt with within one or other of the departments of mechanical engineering, aircraft structures, or chemistry and plastics technology.⁽⁶⁷⁾ In the years around 1940 at least one qualified metallurgist was employed by the Royal Air Force as 'lecturer at the school of aeronautical engineering'.⁽⁶⁸⁾

During the war of 1939-45, a committee was set up by Sir Stafford Cripps, and chaired by Sir Roy Fedden, to make proposals for a post-graduate institution of aeronautics. Resulting from this, in 1946 the College of Aeronautics was created at Cranfield near Bedford. Initially a 'materials' section formed part of the production department, metallurgical instruction being provided by a single lecturer, but in 1957 the section was to be superseded by a separate department of materials headed by Dr. A.J. Kennedy at professorial level.⁽⁶⁹⁾

Government military establishments in the second half of the nineteenth century provided significant proportions of the total numbers who entered for the examinations for the Science and Art Department. The dockyard schools were acknowledged pioneers of 'technical education', albeit of a crude kind. During the 1870s the Royal Arsenal Mechanics' Institute at Woolwich accounted for more than a hundred annual entries in the Science and Art examinations, including a handful for the subject of metallurgy. Around

(67) DENT, H.C.(ed.), op.cit., 230.

(68) VIVIAN, A.C., Essential metallurgy for engineers
(London: Pitman, 1942), title page.

(69) KENNEDY, DR. A.J., personal communication, 1981.

1880 the other great gun factory, situated on the Tyne near Newcastle and run commercially by Sir William Armstrong, also encouraged metallurgical instruction. Later, the veteran of technical education, C.T. Millis, was to point to the fact that the Science and Art Department's choice of subjects and arrangement of syllabuses was influenced by the staff of the naval and army colleges, 'who naturally had experience of the requirements of men needed for ... dockyard and arsenal'.⁽⁷⁰⁾

At Woolwich in 1891 the council of the new Woolwich Polytechnic published its first prospectus, offering a total of thirty-eight classes, but noting that 'practical classes in chemistry and metallurgy will be continued in the Royal Arsenal, as before'.⁽⁷¹⁾ However, in 1904 the secretary of state for war came to an arrangement by which the technical training of Arsenal apprentices was to be undertaken by the polytechnic. The Arsenal Trade Lads were given day release to attend the classes, and had to attend evening ones as well: these have been claimed as the first part-time day classes established in Britain,⁽⁷²⁾ although metallurgy was not necessarily studied in them. The War Office had set an example, but other employers in the neighbourhood were reluctant to follow it. Nonetheless, by 1913-14 there were twenty-six from the Royal Arsenal attending the polytechnic on day release together with twenty-one from other employers: four years later, at the end of the Great War, 184 Arsenal apprentices were enrolled on courses, and in 1920 the number had risen further to 199, supplemented by 45 apprentices from other works.⁽⁷³⁾ At the time when agreement between the War Office and the Woolwich Polytechnic was reached, in 1904, full-time staff were appointed to a number of the polytechnic departments, displacing many of the former part-time teachers; a metallurgist, Godfrey Melland, ARSM, who already had nearly ten years' teaching experience, was appointed to take charge of 'chemistry and metallurgy'. More than twenty years later,

(70) MILLIS, C.T., Technical education its development and aims.
(London: Arnold, 1925), 29.

(71) BROOKS, Collin, An educational adventure a history of the Woolwich Polytechnic. (Woolwich: the Polytechnic, 1955), 27.

(72) BROOKS, Collin, op.cit., 72.

(73) BROOKS, Collin, op.cit., 82; 89-90; 100.

at a time of small demand for metallurgical instruction, particularly when coupled with chemistry, Melland retired and metallurgy was dropped. His successor as head of chemistry in the early 1930s was Arthur Vogel, D.Sc., who became known on a wider front for his several textbooks on chemical analysis.⁽⁷⁴⁾

During the Great War, the engineering and chemistry departments of Woolwich Polytechnic helped the national effort with munitions' production and the analysis of alloys.⁽⁷⁵⁾ Many other colleges throughout the country were also direct contributors to the war effort in a number of ways so that, at any rate for the duration of the emergency, the War Office or the Ministry of Munitions became more important than the Board of Education. In an article on 'Engineering colleges and the war', written jointly by the principal and the head of engineering at Northampton Polytechnic Institute in London and published by the Institution of Mechanical Engineers in the autumn of 1915, the ways in which help might be given were summarised as follows:⁽⁷⁶⁾

- '(1) the testing of war materials, for which the splendidly equipped laboratories of first-class technical colleges and technical departments of the universities are particularly well adapted.
- (2) the testing of new constructional details for military and naval purposes, which can also be well carried out in the same laboratories.
- (3) all kinds of chemical and metallurgical analyses and the analyses of new products for use for warlike purposes.
- ...
- (5) general experimental work of various kinds in connexion with the numerous committees which have been, and are being, organised under the Munitions Inventions Department, the Royal Society, and other public bodies.

(74) e.g. VOGEL, Arthur I., A textbook of quantitative analysis theory and practice. (London: Longmans, Green, first publ. 1939).

(75) BROOKS, Collin, op.cit., 89.

(76) WALMSLEY, R. Mullineux and LARARD, C.E., 'Engineering colleges and the war'. Proc.Instn.Mechanical Engrs., (Dec. 1915), 746.

'(6) the requisitioning of individual members of the staff to give technical advice on subjects in which these individual members are specialists.

(7) the training of drafts from the new armies in intensive short courses for special work. ... '

During the Great War, one of the barriers encountered in turning large numbers of unskilled workers on to work connected with munitions' production and shipbuilding was the obstructive attitude adopted by the engineering trade unions. However, in the University of Sheffield the metallurgy department made gauges for all kinds of munitions' work,⁽⁷⁷⁾ while the melting plant was used for the production of cupronickel and cartridge brass and for the training of melters.⁽⁷⁸⁾ Again, during the war of 1939-45 the University of Liverpool's departments of metallurgy and mechanical engineering became the Air Ministry's regional testing centre for weldments and other fabrication methods used for aircraft components.⁽⁷⁹⁾

The European wars of 1914-18 and 1939-45 produced marked changes in Britain's general education. D.S.L. Cardwell has drawn a parallel between the impact on 'education, scholarship, and learning' of these two wars and that of the Napoleonic period when, 'at a low point in the military fortunes of Prussia, Wilhelm von Humboldt founded the University of Berlin (in 1809): ... the first significant event in the development of the German educational system.'⁽⁸⁰⁾

In the field of higher education, the wars led to empty university departments depleted in staff and, at least during the 1914-18 years, faced with

(77) CHAPMAN, A.W., The story of a modern university a history of the University of Sheffield. (London: Oxford Univ.Press, 1955), 236.

(78) DESCH, C.H., 'The faculty of metallurgy - the University of Sheffield', contribution to CARPENTER, H.C.H., 'Metallurgical education of university rank in Great Britain'. Proc. (1st) Empire Mining Metallurgical Congress, part 5 ..., (London: Instn.Mining Metallurgy, 1925), 55.

(79) KENNETT, S.J., A history of the department of metallurgy and materials science, University of Liverpool 1920 - 1970. (Liverpool: the University, 1970), 11.

(80) CARDWELL, D.S.L., 'Science and world war I'. Proc.Royal Soc.Lond.A, vol.342 (1975), 452.

severe financial crises caused by the curtailed inflow of students' fees. Both war-time episodes were however followed by years of abnormally-high student numbers, Government providing grants to enable many people who had served in the forces to spend periods receiving tuition. These grants for 'further education and training' produced, around 1920 and again in the late 1940s, bulges in the numbers graduating in metallurgy as in other disciplines. In the late 1940s too, school-leavers were given incentive to enrol for university-level instruction because involvement in such advanced courses led to deferment from conscription for national service. The two major wars, moreover, increased the national standing of the universities, both by virtue of the work they did during the emergencies and by the contributions it was felt they could make to the post-war scene.

Britain's military predilections had substantial influence upon the extent of metallurgical instruction available throughout the hundred years from 1851. Stemming from increasing and virtually-unavoidable military dependence upon metals, this influence was applied in several directions. In order to improve the nation's military capability, research into metals and other materials was prosecuted by the various appropriate sectors of the army, navy and, latterly, air force, both within their own service establishments and at other places, including academic departments. Arising from these researches came considerable numbers of publications contributing significantly to the extension of metallurgical knowledge. Job opportunities for metallurgists were created not only in connection with the research programmes but also by State demands for production and fabrication of large quantities of materials for military purposes. Particularly in the years after 1940, employment prospects either directly or indirectly on behalf of military endeavours encouraged students to undergo instruction in metallurgy.

CHAPTER 7

INDUSTRY'S PART IN PROMOTING METALLURGICAL INSTRUCTION

Evidence is scant concerning the promotion from within industry of facilities for metallurgical instruction in the first 70 years of the period between 1851 and 1920; during the remaining 30 years after 1920, considerably more was recorded on the subject. Those engaged within the industry were 'doers' and so it seems reasonable to suppose that, unlike both the agents of Governments and individuals trying to supply instruction from motives of livelihood or altruism, they would not wittingly prepare detailed documents for posterity. The lack of written pronouncements does suggest, however, that, at any rate until after 1920, industry did not do very much to forward formal instruction.

For anyone trying to determine the extent of industry's help, the situation is confused by the blurred dividing line between 'industry' on the one hand and individual industrialists and learned societies supported by industrialists on the other. In fact, from the available evidence it is concluded that the major part of promotion by industry was channelled through societies like the Iron and Steel Institute and the Institute of Metals on a national level, and by similar organisations in the regions, for instance, the Cleveland Institution of Engineers.

British metallurgical industry may be regarded as divided into four sectors, two for non-ferrous metals and two for iron and steel. The two non-ferrous sectors would cover metal extraction and metal fabrication and treatment, while the corresponding divisions for iron and steel would comprise production including rolling to shapes, and fabrication such as the pressing of motor-car bodies and the founding of castings. Of these sectors, by 1900 that of non-ferrous metal extraction had declined relatively to small proportions, a

state of affairs which was to persist through the whole of the first half of the twentieth century and right up to the present time. From the domestic portion of the smelting industry there was thus little demand for metallurgists, although British finance was closely and substantially involved in the pursuit of such activities overseas. It was this overseas involvement in non-ferrous extraction, coupled with the mining of ore deposits, which served to maintain some demand, albeit small, for metallurgists trained at the Royal School of Mines and, after 1900, for graduates from the University of Birmingham.

By contrast with the non-ferrous extractive sector, British iron-and-steel making on a large scale was done within the country, although for much of the period after 1875 this sector was in a state of gloom occasioned by less-than-buoyant markets. The Great War of 1914-18 provided a time of welcome high demand, which was succeeded by conditions of depression until around 1937, when the markets began to improve considerably under the impetus of the national re-armament programme. Even after the change of economic outlook in the late 1930s, however, this sector of the industry, rightly or wrongly, continued to have the reputation of being little interested in sound technical control of its workings, with the concomitant expense and inconvenience occasioned by hiring well-informed technologists and taking notice of their views.

The remaining two sectors of British metallurgical industry, one for ferrous metals and the other for non-ferrous, were both concerned with the forming and shaping of metals to yield useful products, rather than with their production. Some parts of these 'secondary' sectors tended to operate in relatively-small units which were made possible by the nature of their work. It was in these sectors that a good deal of growth was shown with the passing years, as the volume of products turned out increased, and the range of materials employed became wider.

By tradition established over many centuries, as with other crafts, those who produced metal and those who worked it kept the practical details of their procedures and businesses to themselves. Professor W.H.G. Armytage has cited the case of Benjamin Huntsman, the Doncaster clockmaker who, in the 1740s, had found a successful way of improving the quality of steel. Huntsman declined an invitation to address the Royal Society on the subject, but even

so his secret leaked out and was profitably developed by others.⁽¹⁾ In similar way it seems likely that during the eighteenth century the secret of making steel by the cementation process had been carried from the small works in North-east England to Sheffield, where it formed the basis for Sheffield's industry. To some extent, the secretive attitude is still to be found throughout a wide spectrum of commercial metallurgical activity but, as a prerequisite of experience within the industry, in the period since 1851 the value of formal academic instruction has slowly come to be recognised. Formerly, technical knowledge could only be obtained 'on the job', by keeping company with those who were already 'skilled in the art'. This traditional handing-on of knowledge from father to son, or from master to apprentice, in favourable conditions could function effectively. In the reign of Elizabeth I, in 1563 the Statute of Artificers had laid down that 'every craftsman in England had for seven years to learn his craft under a responsible master'. At the end of this time, the man was at liberty to marry, and entitled either to practise the trade independently or 'to become a journeyman for hire'.⁽²⁾ However, with the substantial changes in demand for skilled labour that had come about during the latter part of the eighteenth century it had been found convenient to suggest, judicially, that new crafts were exempt from the statute, and in 1814 the Elizabethan Act was repealed. By this date, in all-too-many cases, 'apprenticeship had turned into forced labour', so that 'it has been said that the industrial revolution was built on the slavery of infants' and 'the factory system degraded the mediaeval craft apprenticeship'.⁽³⁾

Nevertheless even if, in the industrial turmoil and growth of the opening decades of the nineteenth century, the concept of training by apprenticeship had become largely abandoned or abused, for some purposes, and particularly for skilled crafts, the apprenticeship system continued in use. Until after 1950 it was a recognised method of entry to trades connected with the metal industries, such as fitting, bricklaying and turning, as well as to

(1) ARMYTAGE, W.H.G., 'Some sources for the history of technical education in England'. Brit.Jrnl.Ednl.Studies, vol.5 (1957), 79; quoting E.W. Hulme, 'The pedigree and career of Benjamin Huntsman'. Trans.Newcomen Soc., vol. 24, 37-48, (1943-44).

(2) HUNTER, Donald, The diseases of occupations. (London: Hodder and Stoughton, 6th edn., 1978), 24.

(3) PETERS, A.J., 'The changing idea of technical education'. Brit.Jrnl.Ednl.Studies, vol.11, no. 2 (May 1963), 143.

the business side of the enterprises, including management. In her study of certain British industrialists, Charlotte Erickson found that nearly one fifth of 'steel manufacturers' in the second half of the nineteenth century had entered their careers by way of apprenticeships; by the 1930s, however, the proportion had fallen to little more than one twentieth. By these later years, academic training had come to be significant.⁽⁴⁾

The length of time required for 'serving' an apprenticeship also came to be generally reduced from seven years to four or five years, and in some instances ended on the 21st birthday. Thus, around 1880 a common time for an engineering apprenticeship was five years, although numerous commentators agreed that the activities pursued during these five years were often mostly a waste of time and a source of cheap menial labour.⁽⁵⁾ As late as 1905 an instance of a seven-year apprenticeship is recorded for John Rogerson's iron-and-steel foundry at Wolsingham in County Durham, when a lad of fourteen was taken on as an apprentice patternmaker for such a term, being paid 4s. (£0.20) for a six-day week, 9½ hours a day.⁽⁶⁾

Light on the attitude towards training held by some of the Sheffield knife and scissors makers in the early 1880s is shed by the recorded evidence of J. Willis Dixon, president of the town's chamber of commerce, when interviewed by the Royal Commission on the Depression of Trade and Industry. In reply to the question of how he, as a manufacturer, discharged his responsibility for ensuring that youths learnt their trades during their apprenticeships, he stated that in effect he had no responsibility: apprenticeships were attached to workmen not to masters, and the masters had nothing to do with the way the arrangements worked.⁽⁷⁾

Fortunately there were others who took their responsibilities more seriously. Bernhard Samuelson had started in engineering before 1850 and, according to

(4) ERICKSON, Charlotte E., British industrialists: steel and hosiery 1850-1950. (Cambridge: Cambridge Univ.Press, 1959), 42-43.

(5) ROBERTSON, Paul L., 'Technical education in the British shipbuilding and marine engineering industries, 1863-1914'. Econ.Hist.Rev., vol.27 (1974), 225.

(6) ANON. 'A history of the Wolsingham Steel Company Ltd.' (unpubl.typescript). Supplied in 1977 by Mr. T. Armstrong, director and commercial manager, Wolsingham Steel Works. The man whose evidence is quoted was interviewed in 1969.

(7) ROYAL COMMISSION ON THE DEPRESSION OF TRADE AND INDUSTRY, Second report ... with evidence and appendix part 1. (London: HMSO, 1886), Parliamentary Papers vol.21 (1886), Cd. 4715, 20-21.

one view, as chairman of the Royal Commission on Technical Instruction, he 'edited the whole of the Royal Commission report of 1884 with a view to bringing out the advantages of apprenticeship'.⁽⁸⁾ Yet to him is attributed the damning comment, published in 1909, several years after his death, that 'there has been very little teaching by skilled workmen to apprentices within my time'.⁽⁹⁾

In a substantial proportion of apprenticeships it was implicit that a fee, or 'premium', be paid on behalf of the apprentice or trainee by his relatives. This condition severely restricted the numbers of those able to seek apprenticeship. At the same time, such premium apprenticeship, or pupillage, was long recognised as an appropriate means of learning a profession or skilled occupation. In the nineteenth century, and continuing to a lesser extent in the first half of the twentieth, responsible positions in the metallurgical industry were sometimes gained after following the path of pupillage to an established practitioner.

While engineers commonly took pupils in this way, so did some chemists. One of the latter was J.E. Stead, who had served his own pupillage in the late 1860s with J. Pattinson of Newcastle-upon-Tyne, a practising chemical consultant; by 1880, in partnership with his erstwhile teacher, he set up a Middlesbrough office and laboratory. Stead was closely associated with the iron-and-steel industry nationally, and in the 1890s he engaged each year an average of one new pupil or apprentice. Such a pupil, over the course of four years, received 'a rigorous training and a vast amount of responsible practice in the analysis of all raw materials, products and byproducts of iron and steel manufacture'. Normally he was paid nothing in the first year and, in the following three years of apprenticeship, 2s. 6d. (£0.125), 5s. (£0.25), and 7s. 6d. (£0.375) respectively, each week. At the end of this time the young man was paid 20s. (£1.00) weekly as an assistant in the laboratory for any short period before he left. Stead had no difficulty in placing his pupils as iron-and-steel works' chemists, and undertook to do so, their large experience in industrial analysis being a valuable qualification. At the close of the nineteenth century he expected his 'graduated' pupils starting jobs as works' chemists to be paid £100 a year.⁽¹⁰⁾ Stead himself was widely known as a

(8) MUSGRAVE, P.W., Technical change the labour force and education ... 1860-1964. (Oxford, etc.: Pergamon Press, 1967), 92; quoting P. MAGNUS, Educational aims and efforts, (London, 1910), 33.

(9) ROBERTSON, Paul L., op.cit., 225 fn.; quoting ROYAL COMMISSION ON THE POOR LAW, Report, Parl. Papers vol. 37 (1909), 348-349.

(10) MOORE, Harold, 'Some recollections'. The Metallurgist, vol.1, no.1 (Jan. 1960), 30, 32.

consultant on all matters connected with iron-and-steel chemistry and, particularly during the years between 1890 and 1910, he was a leading international figure in the development of the study of visible metallic structures, or metallography.

At any period throughout the century 1851 - 1950 there were several established figures like Stead who were prepared to accept pupils, give them good practical training and, by their standing and influence, secure industrial posts for them. The early full-time college courses in metallurgy largely adopted a similar pattern of paternalism, for instance those in London at the Royal School of Mines under Dr. J. Percy, in Sheffield under J.O. Arnold from about 1890, and in Birmingham soon after 1900. The fact that student numbers were small aided the success of such systems, and the paying of fees, whether for attending a regular college class or for being attached to a works' manager, heightened the similarity.

Even with small numbers, however, there could be difficulty for the student in obtaining an industrial job at the end of his college course. In a narrow and restricted market, there was great need for influence. One example was Percy C. Gilchrist, who graduated from the Royal School of Mines in 1871, but did not take up work as a steel-works' chemist at Cwm Avon in South Wales until around 1875; once inside the industry, he was able to negotiate a move to another works the following year. More than half a century later, in the depressed years around 1930, new graduates at the Royal School of Mines, while waiting for possible jobs to appear, were still having to accept repetitive short-term laboratory work done for the staff. It was because of the difficulty experienced by an outsider in getting into a works that the metallurgy course at the school laid great emphasis on practical assaying and metallurgical analysis: it was believed, probably correctly, that competence in such manipulative yet essential work would help the graduate to obtain a job within industry. Similarly, the mining course at the school placed major stress on surveying. [Not until after 1950 did the school's authorities consider that the limited time available for instruction should be re-distributed, with less weight placed upon mine surveying or metallurgical analysis.] Once the individual, armed with his college instruction, had obtained a foothold within industry, it was left to him to improve his position by whatever personal qualities or other appropriate means he could muster.

Turning again to consider the wider range of jobs offered in metallurgy, during the Great War certain members of the iron-and-steel industry expressed themselves firmly in favour of providing technical instruction for youths beginning employment. These industrialists made up the majority of the Board of Trade's committee convened 'to consider the position of the iron and steel trades after the war', and they reported 'a growing feeling of dissatisfaction with the lack of systematised technical education upon a scale commensurate with needs of the iron and steel industries.'⁽¹¹⁾ Recognising that the two years between leaving school at fourteen and entering the works at sixteen were 'worse than useless' educationally, the committee members recommended that the limit of school age should be raised from fourteen to sixteen. They suggested that a feasible way in which this might be done would be for youths to enter employment at fourteen in the steel industry under a seven-year service agreement with a particular employer. For the first two years of this period the young employee would continue to attend school, where the subjects would include science and mathematics, and during these he would receive a small weekly payment. Then, at sixteen, he would transfer into the industry but, during the next two years, attend technical classes for some six hours weekly as part of his 'general apprenticeship': once the age of eighteen had been reached, it was deemed desirable that 'further education in technical subjects should be given only to those who have given ample proof that they are likely to derive benefit from such instruction'.⁽¹²⁾

The committee's members also expressed themselves in favour of a considerable extension of technical training 'of the university type', with a suitable teaching institution established in each large industrial centre, and with close liaison between industry and the institutions. The report realised that it would be necessary to provide for the ejection at various stages of those unlikely to profit from continued education.⁽¹³⁾

(11) DEPARTMENTAL COMMITTEE ON IRON AND STEEL, Report ... to consider the position of the iron and steel trades after the war. (HMSO, 1918), Cd.9071, 39.

(12) DEPARTMENTAL COMMITTEE ON IRON AND STEEL, op.cit., 41.

(13) DEPARTMENTAL COMMITTEE ON IRON AND STEEL, loc.cit.

These recommendations were submitted to the president of the Board of Trade, the Right Hon. Sir Albert H. Stanley, MP., in 1918. Did the steelmakers who formulated them really believe that, within their lifetime, there was any likelihood of their being implemented? Did their proposals for wider education, both general and technical, for new entrants to the industry reflect views which some of them had held for any longer than the last few war-time years? No answer can be given at present to these questions, but it is undeniable that, following more than a decade of difficult trading conditions, British steel-makers received great prosperity as a result of the war-time demands for their products. Consequently, encouraged by Government promises of a 'better world' once the war was won, the members of the Board of Trade's committee might well have been tempted to take a beneficent view of the situation in the near future. They did state their belief⁽¹⁴⁾

'that economic rearrangements which affect the family budget will be less felt now than at any previous time, and ... that the greater burden laid upon the employer will ultimately tend to his advantage'.

In the event, legislation was enacted in 1918 to raise the school-leaving age, but it was brought to nought by the adverse economic conditions of the 1920s. In similar way, little was to be done towards implementing these sweeping proposals until another generation had come and a second major war had taxed the technological resources of the nation to the utmost. Nonetheless, despite the fact that economic depression after 1920 greatly retarded realisation of most of the proposed developments in technical instruction, some progress was made: substantially more evidence is available for the post-war period than for the preceding 70 years. Perhaps the Great War afforded an opportunity for the crystallisation and enunciation of views which had been slowly evolving among certain industrialists in the preceding one or two decades.

In 1920 the president of the Iron and Steel Institute was Dr. J.E. Stead of Middlesbrough, an ardent campaigner for technical instruction. In his lengthy presidential address he noted how Professor William Ripper of Sheffield University had recently remarked upon the contrast between the position of the

(14) DEPARTMENTAL COMMITTEE ON IRON AND STEEL, loc.cit.

works' chemist then and in the 1890s, when⁽¹⁵⁾

'many of the metallurgical companies in Sheffield did not recognise the value of the metallurgical chemist ... (while) to-day nearly every works had trained chemists, and many of them had perfectly equipped research laboratories'.

Dr. Stead recalled that in the Teesside iron industry nearly half a century earlier, in 1875, only three works considered the services of a chemist to be worthwhile, whereas in 1920 'none, excepting perhaps the smaller foundries, are without their chemical staff'.⁽¹⁶⁾ Giving heartening indication of changing attitudes towards technical instruction which might be found among the workers themselves, he related how, at the suggestion of John Hodge the union leader and first Minister for Labour, it had recently been arranged for him to give a course of lectures for members of the steelworkers' union employed at Dorman Long & Co's new Redcar works. Meanwhile, at another Cleveland works, the Skinningrove Ironworks, the workmen were said to be encouraged to attend lectures on technical subjects, and helped to do so by the works' manager and managing director. Two Sheffield works were also cited: Messrs. Brown Firth, where workmen's technical meetings took place in a lecture theatre of the extensive research laboratory, and Brown Bayley's Steel Works Ltd., where a Ferrets' Society had been established to promote discussion and investigation of technical matters connected with plant practice.⁽¹⁷⁾

Dr. Stead, continuing his address in 1920, went on to speak of 'education' for the staff of works, mentioning the fact that only the previous year, in a letter to the press, Sir Albert Stanley had suggested 'that large undertakings might give more attention to the training and development of their employees'. The speaker commented that in the past the training and development of staff and workmen had been uncommon, and that industry had devoted little expense or effort to encouraging employees to equip themselves with suitable technical knowledge. He told his hearers that⁽¹⁸⁾

'Education is therefore imperative: primary, secondary, and technical education for the youth of the country; and what has

(15) STEAD, J.E., 'Presidential address'. Jrnl.Iron Steel Inst., vol.101 (1920), no.1, 85.

(16) STEAD, J.E., loc.cit.

(17) STEAD, J.E., op.cit., 104-105

(18) STEAD, J.E., op.cit., 105-107.

been sadly neglected in the past, the after-education of the graduates when they enter the works. ... knowledge ... gained (in the works) must be supplemented continuously by study'.

This theme was to be echoed by others in their presidential addresses. For example, a few years later, in 1927, the president of the Staffordshire Iron and Steel Institute remarked in the course of his address that 'It should be the aim of employers to encourage the youths in their employ to attend technical classes and thereby get a knowledge of the technical side of the trade'.⁽¹⁹⁾

Also in 1927, there was published part of a report of a Governmental enquiry, that of the Committee on Industry and Trade, chaired by the steel merchant Sir Arthur Balfour, KBE. This devoted a chapter of 130 pages to the subject of training and recruitment in the various sectors with which it was concerned, 'iron and steel' comprising one of its four main divisions. In the case of 'operatives', the report observed mildly that 'technical training is probably less insisted on at present than is altogether good for the industry'.⁽²⁰⁾

The committee noted that gifts of money or equipment had been made by firms to assist teaching laboratories, but at the same time found that in England there was 'practically no provision' for formal instruction suitable for foremen and others in positions of minor works' responsibility, and that evening schools for boys aged between fourteen and sixteen in iron-and-steel districts did not lead on to specialised classes. In Scotland, however, the situation was less barren, with substantial numbers of classes in existence in iron-and-steel districts, and individuals having some opportunity to proceed to the chief county centres, for example Motherwell and Coatbridge, where the principles of iron-and-steel manufacture could be studied, together with chemistry and mechanics. From these centres in turn, it was considered possible to proceed to classes at the Royal Technical College in Glasgow. The Balfour committee explained the paucity of English technical classes by

(19) WILKINSON, F.S., 'Presidential address'.
Proc.Staffs.Iron Steel Inst., (Oct.1927), 6.

(20) COMMITTEE ON INDUSTRY AND TRADE, Factors in industrial and commercial efficiency being part one of a survey of industries with and introduction by the committee. (London: HMSO,1927), 201.

the facts that during the latter half of the nineteenth century greater encouragement had been given to science than to technology, and that there had taken place 'changes in the organisation of industry'; for these reasons, the growth of instruction had been largely confined to the professional sector with neglect of artisan training. (21)

As far as the advanced, or staff, levels were concerned, the Balfour committee was able to report that courses of metallurgical instruction were available at a number of places. Metallurgy departments were found at several institutions in London, and at Wednesbury and Wolverhampton, while classes were said to be held, and equipment provided for use, at Middlesbrough, Workington, Smethwick, and Frodingham. In Scotland, metallurgical courses and facilities at the Royal Technical College, Glasgow, were given favourable comment. (22)

The confusion that then existed in distinguishing between 'metallurgy' and 'chemistry' is illustrated by the comment that, in addition to 'the principal universities in England and Wales', technical schools at Sheffield, Manchester and Birmingham offered part-time courses in metallurgy together with full-time day courses in chemistry. These latter 'may or may not include iron and steel or metallurgy among the subjects of instruction, but in any case they provide a sound training in chemistry and allied subjects'. (23)

Concerning the effectiveness or otherwise of the formal metallurgical instruction in existence, the 1927 report of the Balfour Committee on Industry and Trade was somewhat equivocal. It observed that, because of the industrial depression, demand for such instruction had decreased during the last few years. At both the subordinate and higher-staff levels, the supply of suitable applicants for work in the iron-and-steel industry exceeded demand; in part, the oversupply of academically-qualified men was attributed to the normal output from the universities four or five years previously, immediately following the war. At the same time, and somewhat contrarily, however, it was declared that within the last few years the iron-and-steel industry had come

(21) COMMITTEE ON INDUSTRY AND TRADE, op.cit., 202.

(22) COMMITTEE ON INDUSTRY AND TRADE, op.cit., 201.

(23) COMMITTEE ON INDUSTRY AND TRADE, loc.cit.

to realise that 'traditional methods must be replaced by those based on the recent remarkable developments in metallurgical science'. As a consequence, demand for 'young metallurgists with the highest scientific qualifications' had been relatively brisk, and had even sometimes outstripped supply.⁽²⁴⁾

In another section of its reports, the Balfour committee affirmed that in recent years the iron-and-steel industry had been criticised for failing to offer inducements sufficient to attract 'men of the highest technical or commercial ability'. It then went on to observe that, according to the evidence of manufacturers, there was at the time 'a much greater tendency than formerly' to appoint selected young men of good education to posts.⁽²⁵⁾ As P.W. Musgrave noted more recently, science graduates began to be recruited to British industry relatively commonly in the 1920s, although a similar interest in the employment potential of arts graduates, especially in the steel companies, appears only to have emerged after the war of 1939-45.⁽²⁶⁾

As far as the training of general labour for the iron-and-steel industry is concerned, it was emphasised that brawn and staying power, coupled with experience of the work to be done, were of greater value than high technical qualifications. Referring to the main branches of the industry and the generality of labour, evidence of the Iron and Steel Trades Confederation in the mid-1920s was that ⁽²⁷⁾

'There is no kind of apprenticeship at all. The ... industry is ... an open gate where anybody with the physical ability and health can come in and take up labouring work ... He gradually ... finds his way into one or other of the different departments of the industry ... and permanent occupations.'

At that period, the proportion of unskilled labourers ranged between one third and two thirds. In foundries, skilled men were required for pattern making, core making, and moulding; at least in some sectors, five-year apprenticeships for the foundry trades were common.

(24) COMMITTEE ON INDUSTRY AND TRADE, loc.cit.

(25) COMMITTEE ON INDUSTRY AND TRADE, Survey of metal industries ... being part 4 of a survey of industries. (London: HMSO, 1928), 37-38.

(26) MUSGRAVE, P.W., 'The educational profiles of management in two British iron and steel companies with some comparisons, national and international'. Brit.Jrnl.Indust.Relations, vol.4 (1966), 210.

(27) COMMITTEE ON INDUSTRY AND TRADE, part 4, op.cit., 38.

Two or three years after publication of the Balfour committee's findings there was issued, in 1930, a report on 'Education for industry and commerce' in the West Midlands metal-working area. Unlike the Balfour reports, which metallurgically were concerned solely with the situation in the iron-and-steel industry, the 1930 pamphlet prepared by the Board of Education considered technical instruction for all trades in the specific area; moreover, in the West Midlands these embraced a wide range of metals and their treatment. It was remarked that in Birmingham there were more people engaged in metal working than in any other English town, while in Smethwick, 'nearly half the occupied male population ... (were) metal workers, mainly concerned with non-ferrous metals ... brass, zinc, copper, tin and aluminium, but also with the making of bolts, nuts and screws'.⁽²⁸⁾

On the side of progress the 1930 pamphlet reported that since the Great War co-operation between industry and schools had increased considerably, and that employers frequently paid the fees of students attending evening classes. In addition, advisory committees involving industrial representatives had been established in several centres; these had had the effects of helping colleges to offer suitable curricula, encouraging young industrial workers to attend college classes, and supplying equipment for college laboratories. Such advisory committees had been set up in Birmingham for subjects including plumbing, metal-plate work, and gun-making, and at West Bromwich for engineering. Discussions had taken place between industrial employers and the local educational authorities to explore the possibilities for increasing the industrial usefulness of colleges: at Wednesbury these talks had been concerned particularly with foundry work and production engineering, while in Birmingham they had been on the provision of courses for young workers in the brass and copper trades.⁽²⁹⁾ However, it was judged that considerable scope remained for further developments. One of the most important facets for co-operation was deemed to be potential encouragement by employers to workers to attend part-time courses, for⁽³⁰⁾

'Release of employees to attend day classes is ... the exception;

(28) BOARD OF EDUCATION, Education for industry and commerce.
The West Midlands metal working area.

(London: HMSO, 1930), 18.

(Board of Education, educational pamphlets, no.74)

(29) BOARD OF EDUCATION, op.cit., 39.

(30) BOARD OF EDUCATION, op.cit., 14.

'usually, attendance is at evening classes, for which students are sometimes allowed to leave the works before the ordinary hour in the afternoon.'

A point to stand out clearly from the Board of Education report is the great difficulty experienced by the author(s) in making a satisfactory delineation of the scope of 'metallurgy': one problem was to distinguish between what constituted 'metal working' and what 'engineering'; another was that in most instances where technical-college instruction in metallurgy was cited, it was closely associated with chemistry, so that classes and departments of 'chemistry and metallurgy' tended to be bracketed together. This lack of definition of 'metallurgy' is one of the chief factors which for many years has bedevilled its development as a profession.

The report attempted to classify the West Midlands' metal industries into 'preparatory processes', which involved some 52 000 employees at the 1921 census, and 'secondary processes', in which roughly 165 500 employees were engaged, Table 7.1. At the same time, another 158 500 people in the area were involved in the manufacture of plant, machinery and vehicles, activities construed to be 'engineering' as distinct from metal trades. According to the census returns of 1921, West Midlands' workers in the sectors associated with 'iron or steel tubes' accounted for nearly three quarters of all such workers in England and Wales, while those employed in 'non-ferrous metals, rolling mills and tube and pipe making' comprised two thirds of the total.

For the 'preparatory processes', the report found there had been little or no demand for formal instruction for either unskilled or skilled workers. It was concluded that⁽³¹⁾

'Technical education, so far as it influences these industries, does so through persons concerned with control and direction, for whom subjects like engineering, metallurgy, and chemistry may be very useful.'

(31) BOARD OF EDUCATION, op.cit., 41.

Table 7.1 : classification of metal industries in
the West Midlands area, 1920s

(a) Preparatory processes	iron and steel smelting, converting, refining, rolling and forging other metals and alloys extracting and refining iron or steel tubes rolling mills, and tube and pipe making non-ferrous metals
(b) Secondary processes including manufacture of metal articles	foundries iron, steel, brass and other metals forging chains, anchors, etc. small tools cutlery, files, saws, others miscellaneous products pins, needles, fish hooks, bolts, screws, rivets, locks, weighing machines, bedsteads sheet-metal goods small arms

BOARD OF EDUCATION, Education for industry and commerce. The West Midlands metal working area. (London: HMSO, 1930), 40; 64-65.
(Board of Education, educational pamphlets, no.74).

A Ministry of Labour inquiry made in the mid-1920s into apprenticeship and training for skilled occupations in the metal trades had found there were some apprentices and learners engaged within certain trades, but the number and the proportion compared with those in the engineering industries were both small. Figures quoted by the 1930 Board of Education survey bear out, depressingly, the low level of formal instruction in metallurgy, Table 7.2. Whereas in 'engineering' about three per cent. of employees attended classes, in 'metallurgy' the proportion was only 0.2 per cent., or only one sixth as high. It seems reasonable to presume that in a good many cases instruction

in either metallurgy or engineering would have had equal relevance to the actual requirements of the students and their work. Indeed, the report acknowledged that an unknown number of metal industries' employees attended engineering courses, and that 'several hundred' took courses in pure chemistry.

Table 7.2 : numbers of students of engineering and metallurgy in the West Midlands, 1927-28

	<u>Engineering</u>	<u>Metallurgy</u>
Numbers of industrial employees (1921 census)	158 561	217 500
Numbers of students attending classes		
full-time	35	3
part-time during day	1035	31
evening -senior	3451	282
" - advanced	<u>329</u>	<u>74</u>
totals	<u>4850</u>	<u>390</u>
as percentage of employees	3.05	0.18

BOARD OF EDUCATION, Education for industry and commerce. The West Midlands metal working area. (London: HMSO, 1930), 44.
(Board of Education, educational pamphlets, no.74)

With regard to the British steel industry, in 1930 the Journal of Careers, formerly the Schoolmaster's Calendar, published three articles extolling the attractive employment prospects for the fortunate youths selected for future staff positions. The first of these articles, written under the name of Sir Arthur Dorman, chairman of Dorman Long & Co. Ltd., informed readers that the company preferred to recruit the majority of its staff between the ages of fifteen and eighteen, and that 'the early part of their service may be regarded as specialised instruction in the work they have chosen as a career'. A boy who was prepared to attend evening classes with regularity, and who cultivated a 'desire to learn instead of to pass the working hours with the

minimum of exertion', would find openings to promotion; the company encouraged and assisted employees to attend evening lectures at the technical college in Middlesbrough, then newly opened. Up to that time, the number of men with university qualifications who had entered Dorman Long's service had been small, but conditions were acknowledged to be changing.⁽³²⁾

The second recruiting article in the series was prepared by the employment superintendent of the United Steel Companies Ltd., and it gave details of the two apprenticeship schemes then operated by the company for aspirants to staff status. The 'school apprenticeship' scheme was applicable to selected boys aged at least seventeen years and possessing good school records, and it covered a four-year period: 'generally, school apprentices will spend one year in the laboratory and cost department at a selected works ... another year at blast furnaces with their associated mines and quarries; a third year in melting shops and mills.' During the fourth year training was directed towards a particular specialism such as works' management, technical control, or the commercial side. A condition of this school apprenticeship was attendance at an approved institution providing a systematic course of technical study; the apprentice was expected initially to pay his own fees for this instruction, but the money would be refunded later by the company if progress was satisfactory.⁽³³⁾ This arrangement was to be continued for more than twenty-five years, into the 1950s; at the later date, students who attended evening classes were to be allowed to start work on the following morning at 9 a.m. instead of 7.30, and technical apprentices aged eighteen were to be expected to obtain during the next three years of their indentures higher national certificates in metallurgy. Progress was to be encouraged by the presentation of company prizes.⁽³⁴⁾

(32) DORMAN, Sir Arthur, 'Opportunities in the steel industry'.
Jrnl. of Careers, (April, 1930), 11-13.

(33) GREIG, Edward C., 'Opportunities in the iron and steel industry.
Training scheme of the United Steel Companies Ltd.'. Jrnl. of Careers, (June, 1930), 18-22.

(34) WILSON, W.T. and others, 'Education and training', in ANON.,
Iron and Coal Trades Review: a technical survey of the
Appleby-Frodingham Steel Company (a branch of the
United Steel Cos. Ltd.),
(London: Industrial Newspapers Ltd., c.1957), 371-372.

The other training scheme offered in the 1930s by the United Steel Companies was 'college apprenticeship' for a period of two years, and this was open to young university graduates, of whom about six were selected each year. The training was said to be intensive,

'consisting of four months at blast furnaces, four months in melting shop, and eight months in mills and finishing departments.

Two months are then spent in the testing department ... An apprentice selected for works' management devotes the last six months of his training to the design and calculation of plant (drawing office), technical information (research department), and cost accountancy.'

College apprentices were paid £2.50 a week throughout the two years, whereas school apprentices started with pay of 17s. (£0.85), rising to £1.40 in their fourth year.⁽³⁵⁾

The third of the Journal of Careers articles on the steel industry was contributed by Sir Robert A. Hadfield, who made the point that a number of university-trained men had been recruited for metallurgical work in his company's research department, and that all responsible positions in that department were held by graduates. In the works, most of the apprentices were recruited from elementary schools to learn skilled trades, but a few candidates with matriculation or school certificate were taken on; given suitable personal qualities, a boy who resolved to improve his knowledge by part-time evening classes in metallurgy or engineering could advance to interesting and responsible work. On the metallurgical side, managers, shop foremen, and other assistants of high technical ability were required.⁽³⁶⁾

Following the three articles advertising careers in the steel industry, the Journal of Careers published a broader view, 'Good prospects in metallurgy', by Dr. F.C. Thompson, professor of metallurgy in the University of Manchester. In this were mentioned opportunities for university-trained men in research laboratories, both Government-run and commercial, and the fact that the newer metallurgical industries, such as those dealing with nickel and

(35) GREIG, Edward C., op.cit., 21.

(36) HADFIELD, Sir Robert A., 'How a famous steel firm recruits its staff'. Jrnl. of Careers, (Dec. 1930), 23-26.

aluminium, were increasingly coming to appreciate the value of university training. Professor Thompson outlined how an honours degree in metallurgy might be obtained, and even included a paragraph on women graduates, for whom he thought employment in the metallurgical industries was 'confined almost exclusively to the research laboratories and to posts as librarians'. He observed that as research workers 'a few women have made reputations for themselves of which many men might be proud, and two at least have received the D.Sc. for distinguished metallurgical research.' However, he cautioned that for female graduates who were less than first class, employment prospects were poor, and they might even experience difficulty in obtaining teaching posts in school science.⁽³⁷⁾

A dozen years later, during the war of 1939-45, a committee in the Lincolnshire town of Scunthorpe considered that the value of industrial apprenticeships had fallen because of the demise of the former idea that such apprenticeships related 'to responsibility as well as to skill'.⁽³⁸⁾ Some weaknesses of the customary methods of trades' apprenticeship were revealed by war-time demands for rapid production and the application of technical developments. Echoing the recommendations put forward in 1916-18 by the Board of Trade committee during the Great War, the Scunthorpe group hoped that contributions to better training would be provided by the Young People's Colleges which were at that time proposed. In addition, for the operatives employed in the production departments of the iron-and-steel works in the Scunthorpe district, the committee urged that training 'of a general technical nature' should be instituted, which should include instruction at the local technical school.⁽³⁹⁾ In 1943-44, as an experiment, on one day a week twenty-five young steelworkers attended the school in working hours for 'pre-apprentice education'.

In addition to some employers being prepared in certain districts to support formal metallurgical instruction by assisting employees to attend classes, aid from industry contributed to the facilities needed to establish

(37) THOMPSON, F.C. 'Good prospects in metallurgy. Scope for men and women'. Jrnl. of Careers, (Feb. 1931), 11-15.

(38) LINDSEY COUNTY COUNCIL EDUCATION COMMITTEE, Technical education in Scunthorpe and district. (Lincoln: Lindsey County Council Education Committee, 1944), 28.

(39) LINDSEY COUNTY COUNCIL EDUCATION COMMITTEE, op.cit., 16.

and maintain such tuition. For instance, in the 1880s the Sheffield steel manufacturer Thomas Jessop gave money to help support the town's new technical school:⁽⁴⁰⁾ in fact, he was the only steelmaker to do so at the time, although twenty years later, when endowment of the new University of Sheffield called for the large sum of £170 000, another steelmaker, Edgar Allen, offered £10 000 on condition four others would subscribe similar amounts.⁽⁴¹⁾ In the years between 1910 and 1935 a third industrialist noted for his metallurgical achievements, Sir Robert A. Hadfield, supported the technical departments of the university to the extent of more than £25 000, while various others provided items of equipment or furnishing. When a course in foundry science was begun in 1934, subscriptions from industry, together with gifts of plant, sufficed to create a model foundry.⁽⁴²⁾ However, shortly after the end of the Great War a number of prominent industrialists in the Sheffield district were canvassed unsuccessfully for money to maintain a second chair of metallurgy at the university,⁽⁴³⁾ where for some years Professor Arnold had liked to distinguish two departments, one in 'iron-and-steel metallurgy' and the other in 'non-ferrous metallurgy'.

Seemingly far removed from the metallic toil of Sheffield was the University of Cambridge, where a metallurgical readership was established in 1908 with funds from the Worshipful Company of Goldsmiths, which also helped with the building of laboratory accommodation. In the early 1930s further endowments from the same source raised the post to the status of a chair, the Goldsmiths' Professorship in Metallurgy. A few years later, the Iron and Steel Industry Research Council contributed towards new equipment for the Cambridge metallurgical laboratories, and examinations in metallurgy of honours-degree standard were started. The Goldsmiths' company can be regarded as a body comprising many individual members, and as a London livery company deriving at least a portion of its wealth from industry in precious metals.

(40) ERICKSON, Charlotte E., op.cit., 41; quoting CHAPMAN, A.W., The story of a modern university a history of the University of Sheffield. (London, Oxford Univ.Press, 1955), 38-39.

(41) ANON., 'News items'. Page's weekly, vol. 6 (24 Feb. 1905), 395.

(42) ANDREW, J.H., 'The department of metallurgy, University of Sheffield'. Bull.Instn.Metallurgists, vol.2, (1950), 29.

(43) CHAPMAN, A.W., The story of a modern university a history of the University of Sheffield, (London: OUP, 1955), 311.

After 70 years of the century 1851 - 1950 had already expired, a chair in metallurgy made possible by industry was also instituted in the University of Liverpool, and in the 1950s similar chairs were to come into being at Nottingham and Swansea. In Liverpool in 1920, the Henry Bell Wortley Professorship in Metallurgy was founded by a gift of £10 000 from Alfred Holt & Co. of the Blue Funnel Shipping line in memory of a late partner. A condition of the appointment of the first professor was that he was to develop metallurgy 'with special reference to engineering and naval architecture'.⁽⁴⁴⁾ Ten years later Alfred Holt & Co. provided substantial hospitality in Liverpool for 'the intervarsity conference of metallurgy students' which was active for a short period, 1925 - 1930. The Nottingham metallurgy chair was to be funded by Cripps' Industries Ltd., while a second metallurgy chair at Swansea was to be created in the mid-1950s as the result of a total of £50 000 provided over ten years by Richard Thomas and Baldwins and the Steel Company of Wales.⁽⁴⁵⁾

Evidence of local industrial support on an appreciable scale is available for several other districts. Thus, of the metallurgy department in the University of Birmingham it was stated in 1924: 'the local industries have afforded generous ... support; they also permit students to visit their manufactories, and find openings for trained metallurgists'.⁽⁴⁶⁾ Advertisements for potential students which appeared in the 1930s expressed similar sentiments in respect of the University College of Swansea.⁽⁴⁷⁾ In the period 1945 - 1950 metallurgical instruction at Birmingham was expanded and modified by creation of departments of both 'industrial metallurgy' and 'physical metallurgy', with multiple professorships. Acknowledgement was then given to 'the metallurgical industry of the country', which had 'endorsed the necessary material conditions

(44) KENNETT, S.J., A history of the department of metallurgy and materials science, University of Liverpool 1920 - 1970. Liverpool: the University, 1970), 2.

(45) DYKES, D.W., 'The University College of Swansea', in BALCHIN, W.G.V.(ed.), Swansea and its region. (Swansea: the University College, 1971), 359. The sums provided by industry amounted to £100 000, of which £50 000 was for laboratories.

(46) TURNER, T., 'University of Birmingham', contribution to CARPENTER, H.C.H., 'Metallurgical education of university rank in Great Britain'. Proc.(1st) Empire Mining Metall.Congress, part 5, (London: Instn.Mining Metallurgy, 1925), 45.

(47) ANON., 'University College of Swansea'. The Metal Industry, vol.51 (2 July 1937), advt. p.22.

for ... success ... by generous covenanted subscriptions and donations of money and equipment'.⁽⁴⁸⁾ In London, in the opening years of the present century the newly-constituted Imperial College received substantial industrial support, notably with gifts of £100 000 from Wernher, Beit & Co., and £50 000 from Alfred Beit himself.⁽⁴⁹⁾ These greatly helped realisation of the new building for the Royal School of Mines on Prince Consort Road. Then, shortly before the Great War, wide support was obtained for equipping the Bessemer Memorial Laboratory of the school, much being made of the fact that well-equipped testing facilities would be useful to London-based metal-producing companies, even though the sites of their actual operations might be widely distributed throughout the world.

With the re-vitalisation of metal production which resulted from the war of 1939-45, it became possible once again to attract substantial funds for promoting training and research in the neglected field concerned with the ex-traction of non-ferrous metals from their ores. The Nuffield Foundation, which derived its funds from profits in the motor-vehicle industry, provided money for setting-up, within the Royal School of Mines, a Nuffield Research Group in Extraction Metallurgy. Formed in 1949, the group was headed by a fellow, Dr. F.D. Richardson, with two permanent staff members. The object was fundamental investigations, 'with particular emphasis on the physico-chemical background of extraction and refining' of metals.⁽⁵⁰⁾ The group was said to be almost the only one of its kind in the Commonwealth. The five post-graduate students who joined it in the session 1949-50 were supported by grants provided by the British Iron and Steel Research Association, the Associated Lead Manufacturers, and the DSIR.⁽⁵¹⁾

(48) MURPHY, A.J., foreword to SINGER, A.R.E., 'Industrial metallurgy at Birmingham University'. The Metal Industry, (21 Sep. 1951), 235.

(49) SANDERSON, J.M., The universities and British industry 1850-1970. (London: Routledge and Kegan Paul, 1972), 116.

(50) RICHARDSON, F.D., 'The Nuffield Research Group in Extraction Metallurgy' Jrnl.Mining Metall.Soc.Royal Sch.Mines, (1949-50), 32.

(51) RICHARDSON, F.D., op.cit., 33.

Industrial aid was not confined to staff salaries, buildings, and items of equipment. Students themselves received help in several ways: with fees and support while attending formal courses of instruction, with opportunities for obtaining works' experience, and with job offers at the successful conclusion of instruction. Help from employers with fees for evening-class instruction seems to have been reasonably common but, by their nature, scholarships or sponsorships to undertake full-time courses were few and far between, though some did exist in the later years of the period 1851 - 1950. For instance, in the Scottish steel industry, the Colville Group had a scheme which enabled 'selected junior employees' to undertake degree courses; it claimed there had been 'some remarkable instances of young men who have responded to the challenge of the opportunities provided ... '(52)

One interesting and relatively-early form of industrial aid was the scholarships offered from around 1900 to graduates in metallurgy, mining, and allied fields. At the rate of two or three a year, these scholarships provided passages to and from either Western Australia or South Africa, together with maintenance while at a particular metallurgical plant for a period of a year or more. Administered by the Institution of Mining and Metallurgy, these scholarships to gold-producing districts gave the chance for selected young graduates to discover whether they could stand work at the properties to which they were drafted, while potential employers had the opportunity to find suitable new recruits for their staff. In the years up to 1910, post-graduate scholarships of this sort were awarded to graduate students from Birmingham, Glasgow, Sheffield, Durham, London, and the Camborne School of Mines in Cornwall. These post-graduate awards seem to have ended with the Great War, but some thirty years later scholarships for post-graduate and under-graduate study tours of overseas metallurgical plant became available as the result of benefactions from the Nuffield Foundation. For a number of years from 1947 the Nuffield Foundation aided tuition in extractive metallurgy by providing up to twenty travelling scholarships each year to enable those selected to extend their knowledge and experience by visiting important mining and metallurgical centres for periods of three or six months. Each year, five of the scholarships, worth up to £500 each, were for teaching staff of

(52) ANON., Iron and Coal Trades Review: a technical survey of the Colville Group of Companies. (London: Iron Coal Tr.Rev.,n.d., c.1957), 233.

universities and schools of mines, another five of similar value were for 'junior members of the profession who are graduates', and the remaining ten awards were for vacation studies by under-graduate students.⁽⁵³⁾ At much the same time, the Mond Nickel Company, through the company's managing director Dr. Griffith, encouraged the same field of extractive metallurgy by making generous grants for short-term travelling fellowships.

Besides the scholarships mentioned, in 1949 awards available from industrial sources to those studying metallurgy, among other disciplines, included: Turner and Newall, £600 at Manchester University and another £600 at Leeds University; Imperial Chemical Industries Ltd., £600 at Leeds University; the Goldsmiths' Company, value £400, age under 24, for travelling; the Founders' Company, £300 for research and study in the foundry industry; Beit Fellowship value £400 at Imperial College, awarded to promote scientific research; Yorkshire Copper Works, £300 at Leeds University, open to graduates intending to pursue research in non-ferrous metallurgy; and three smaller awards at Sheffield University for research in metallurgy.⁽⁵⁴⁾

One further way in which commerce has aided metallurgical instruction over the years, albeit sometimes in decidedly-niggardly fashion, has been in allowing students to visit works and other industrial installations. These visits have been of two kinds: rapid 'sight-seeing' tours of a few hours' duration, generally made by a group; and extended visits by individuals who might spend a vacation of ten or twelve weeks in one company. The opportunities for gaining industrial experience afforded by the latter visits have been extremely valuable. About 1918 Professor H.C.H. Carpenter of the Royal School of Mines stated emphatically that students who expected to occupy technical positions in works should have obtained industrial practice in conjunction with their 'educational training'. For many years satisfactory completion of works' experience during long vacations was an essential part of the course requirement for metallurgy students of the school. Professor Carpenter's views were endorsed by the president of the Institute of Metals, an

(53) ANON., 'Muffield Foundation fellowship'. Colliery Guard., vol. 173 (27 Sep. 1946), 394.

(54) ANON., 'Post graduate scholarships and fellowships'. Bull.Instn.Metallurgists, vol.2, no.1 (Mar.1949), 21-25.

industrialist, in 1922, with the statement⁽⁵⁵⁾

'That student who has had works training together with his theoretical training is a far better man to hold a technical position in a works than a man who joins a technical staff with purely a theoretical training.'

Even before 1920, however, on at least one occasion, the virtue of offering facilities for vacation students was praised. In 1910 the managing director of the Skinningrove Ironworks in North-east Yorkshire, T.C. Hutchinson, in his presidential address to the Cleveland Institution of Engineers, reported how under-graduate students of metallurgy and engineering had been allowed inside his works for several summers.⁽⁵⁶⁾

'They took up the ordinary work of the blast furnace men, working on the day and night shifts in regular rotation. They were coke-runners, mine-fillers, and chargers in turn, and on the front side assisted in tuyering, slagging, and running the pig iron ... They took out time boards and were paid the ordinary wages of the job. They treated the workmen as comrades ... '

This sympathetic attitude may have been influenced by the fact that T.C. Hutchinson's son, Arthur, had himself studied at Cambridge.

Since about 1934 a scheme to help students of various disciplines to obtain places for experience by vacation work has been operated by Imperial College. In 1941 organisations accepting students under the scheme included: Stewarts and Lloyds Ltd., the Staveley Coal and Iron Company, John Summers and Sons of Shotton, and the United Steel Cos. Ltd.⁽⁵⁷⁾ In 1946 the Imperial College scheme was extended to include international exchange of students for vacation work, a development which entailed equal numbers coming from abroad and going abroad. In the first year, 1946, a total of 46 students, home and foreign, participated. The following year 105 Imperial College students were

(55) SUMNER, Leonard, 'Presidential address'. Jrnl.Inst.Metals, vol.27 (1922), no.1, 45-46.

(56) HUTCHINSON, T.C., 'Presidential address'. Proc.Cleveland Instn.Engrs., (1910-11), 22.

(57) ANON., 'Imperial College of Science and Technology, vacation work scheme'. Colliery Guard., vol.172, no. 4438 (18 Jan. 1946), 104.

involved, together with 116 coming to this country from abroad.⁽⁵⁸⁾

The evidence shows that industrial support for formal instruction in technological subjects including metallurgy was appreciable in the years up to 1950. But not everywhere and not at all times was enlightened beneficence coupled with close harmony between industry and academics. By no means all employers, especially in the earlier part of the period 1851 - 1950, were prepared to assist their employees to attend evening-class instruction outside working hours, and there is no doubt that the school provided by the armament and machinery maker, William Armstrong, at his Elswick Works on the River Tyne near Newcastle was highly exceptional. There, in the early 1880s,⁽⁵⁹⁾

'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'.

Charlotte Erickson has quoted the view which S.R. Lysaght attributed to his imaginary, but presumably realistic, steelmaker of the 1870s who advised a young job applicant to begin his working life immediately, even though, or perhaps because, this would mean quitting university in mid course; a degree he held to be of no commercial use, and 'he considered that the university life was too easy and pleasant, making it all the more difficult for a young man to face the daily routine of an office'.⁽⁶⁰⁾ Even in the early part of the twentieth century, the Sheffield steelmaster W.H. Ellis, speaking to the Sheffield Society of Engineers, reported a feeling in the industry⁽⁶¹⁾

'that young men with engineering or science degrees had spent too much time in theory to have the necessary workshop experience, and that such degrees stood in the way of their obtaining positions in the industry.'

(58) ANON., 'Imperial College Union, vacation work scheme'. Colliery Guard., vol.175 (12 Dec. 1947), 826.

(59) HUXLEY, T.H., as witness before the Technical Instruction Commission, October 1882. Reproduced in RUSSELL, C. and GOODMAN, D.C., (eds.) Science and the rise of technology since 1800, (OU Press, 1972), 154.

(60) ERICKSON, Charlotte E., op.cit., 35; quoting LYSAGHT, S.R., My tower in Desmond (London: Macmillan, 1925), 110.

(61) ERICKSON, Charlotte E., op.cit., 36; quoting STAINTON, J.H. The making of Sheffield, 1865-1914, (Sheffield: Weston, 1924), 142.

Nearly twenty years later, a few years after the Great War, the president of the Institute of Metals posed the question of why, among the abundant available numbers of 'trained metallurgists, chemists, (and) engineers', there was great difficulty in finding 'the right man for the managership'? He requested

'our professors and teachers to ... ask themselves why it is that students they have trained so carefully ... do not rise, generally speaking, to take those higher positions ... to which it would seem their training would eminently fit them.'

He suggested that academic training should be broader rather than so specialised, and that students who were 'not so clever' were comparatively neglected by the teachers' interest in those who were 'brilliant'. He commented that academics 'seemed to overlook the fact that industry requires many sound and able men and but a few brilliant men'.⁽⁶²⁾

In the period of low trading activity which continued until the middle 1930s, employment prospects for metallurgists were small. There was little incentive for industrial employers to hire fresh metallurgical graduates, such action being commonly regarded as ill-affordable, and possibly misguided, luxury; if it happened that a new technical employee was required, a technician would be preferred to a graduate. In these years, many parts of British industry were struggling to ward off the spectre of bankruptcy.

It is little wonder that, of the small number of those who graduated from university metallurgy departments during this period, a relatively high proportion stayed on in academic surroundings to gain experience of 'research', or took work devilling for their professors while waiting for possible jobs. Of those graduates who did move out from university seclusion into the harsh commercial world, it seems likely only a minority succeeded in finding employment which effectively used the training previously received. A significant proportion emigrated. From this evidence, British industry in the 1920s and 1930s certainly did little to encourage the growth of metallurgical instruction.

An exception to the overall bleak outlook for employment was provided by the industrial research associations which were formed to serve groups of

(62) SUMNER, Leonard, op.cit., 47-48.

companies engaged in similar activities. These associations were fostered by the Government's Department of Scientific and Industrial Research. Both by sponsored research in university departments, and in investigations and developments pursued within industrial premises, they provided employment opportunities for at least a handful of metallurgical graduates as well as for some supporting workers.

Towards the close of 1937 there appeared an editorial leader in a weekly trade journal, provoked by the presentation of a paper to the London local section of the Institute of Metals on 'The training and employment of metallurgists'. The paper's author was the professor of metallurgy in the University of Cambridge, Dr. R.S. Hutton. The leading article roundly observed that 'there are far too few students of metallurgy to satisfy the needs of industry', but then went on to draw^a distinction between 'needs' and 'desires', because 'even the small number of metallurgists ... who graduate from the universities every year, have difficulty in obtaining suitable posts in industry'. One of the reasons for the poor position of the British metallurgist was identified as 'the apathetic attitude of industry towards its needs'; this, in turn, was said by some to stem, at any rate in part, from the 'sparse representation of university-trained men on boards of directors', which compared unfavourably with the corresponding situation in Germany and the USA. Another reason adduced for the neglected status of the metallurgist was 'the lack of properly-directed publicity in regard to metallurgy as a profession'. With this was closely allied the fact that rewards were small, many graduates holding appointments providing between £100 and £200 a year in salary while in addition, perhaps, receiving 'the maximum lack of sympathy and understanding' in performing their jobs. £100 would then have been almost enough to purchase a new small motorcar. The works' metallurgist was said to be 'generally over-worked and under-paid' and the relationship between metallurgists and industry was 'to say the least, disturbing'.⁽⁶³⁾

At the time this was written, doubtless all its scathing criticisms were justified, and had been for many years previously. However, the tide was already beginning to turn, and the situation of full technological employment

(63) ANON., 'The metallurgist, his training and employment'.
The Metal Industry, vol.51, no.21 (19 Nov. 1937), 495-496.

associated with the war of 1939-45 gave an opportunity for some amelioration in attitudes and conditions. A leading academic, Dr. Leslie Aitchison, could write in 1946 that, in contrast with the bad old days when industrialists used university men trained in metallurgy only as backroom boys, the 'leaders of industry now realised that men with a university training possessed real assets'.⁽⁶⁴⁾ But old attitudes die hard, and it was to be many years before prejudices could be largely overcome.

Michael Sanderson has drawn attention to the fact that interaction between institutions of formal instruction and industry provided benefits in both directions: while in some cases industry supported formal metallurgical instruction, the institutions supplying the instruction could also be of considerable help to industry. In certain circumstances, local industry obtained much-greater value than it was prepared to give.⁽⁶⁵⁾ One illustration of the difficulties of combining industrial and academic interests is afforded by certain claims with which Professor J.O. Arnold of Sheffield was involved. A prickly character at the best of times, in 1909 he complained of demands by some industrialists that the university's 'scientific lecturers ... should be compelled ... to make such lectures always subservient to the trade interests'; he described these demands as an attempt 'by a limited number of manufacturers to dictate to its professors'. Arnold was also accused by one steel company, Firth's, of 'using public university money to carry out secret investigations and ... passing secret information to one firm, Jonas and Colver'.⁽⁶⁶⁾ This accusation was just one episode in a long-running battle; twenty years earlier, when Arnold had recently been appointed professor in Sheffield, his consulting practice was the cause of difficulties.⁽⁶⁷⁾ Industrialists were distrustful of the confidentiality of dealings with academics.

In marked contrast with the depressed situation of the 1920s and a number of earlier decades, the last few years of the period 1851 - 1950 witnessed

(64) AITCHISON, Leslie, 'Meeting industry's needs', in 'Training industrial metallurgists; new course at Birmingham'. The Chem. Age (metall. section), vol.54 (1 June 1946), 610.

(65) SANDERSON, J.M., op.cit., 120.

(66) SANDERSON, J.M., op.cit., 102; quoting MS letters of J.O. Arnold, 1909.

(67) CHAPMAN, A.W., op.cit., 75.

industry, and notably the constituents of the aircraft industry, providing a fair amount of encouragement to metallurgical instruction. Jobs were offered to those who had received such instruction, and help by way of equipment and information was given to teaching establishments. The years following 1945 also saw the beginning of developments in peaceful uses for atomic energy, as well as in the British atomic bomb. This new 'nuclear' industry offered employment to metallurgists in a variety of ways, ranging from the extraction of uranium from its ores, to the many tasks involved in devising, fabricating and controlling the situations in which radio-active uranium could be made to generate energy, both with devastating suddenness and usefully and safely.

The future then looked bright: after a hundred years of struggle by the few, and apathy and parsimony by the majority, industrial demand for instruction in metallurgy on an appreciable scale had become a reality.

CHAPTER 8SCIENTIFIC SOCIETIES AND EDUCATIONAL ORGANISATIONS:the role of bodies not predominantly concerned with metallurgy

From the earliest times, people have banded together to pursue common aims with greater success than could be accomplished by individual efforts alone. The professions of law and medicine had early protected themselves by the formation of societies which were operated very much to their own advantage. The trades involving metals, such as goldsmithing, armoury, nailing and needle-making, had been regulated by guilds and by law in the larger English towns from the sixteenth century. The development of technical education in general, and that in metallurgy in particular, are no exceptions to the pattern of behaviour, groups having played major parts in the development of both. For present purposes, groups having two broad kinds of influence can be usefully distinguished: those affecting developments on a wide front, and those promoting narrow ranges of interest. Examples of the former are the Royal Society, the British Association for the Advancement of Science, and the Society of Arts; while among the latter are the Iron and Steel Institute and the Institute of Metals. The London trade guilds, although created specifically to forward the interests of particular restricted groups, by the mid-nineteenth century and collectively, had lost many of their original objectives: shortly afterwards, however, in the 1870s they were to gain new significance as sources of money for the development of technical education.

In the 1850s British metallurgists certainly had no group to represent their interests. Anyone who wished to learn of fresh technical developments in the metallurgical field had few opportunities open to him. If he possessed sufficient means to pay the subscription and travel to wherever meetings were held, he might support the British Association for the Advancement of Science.

If, in addition to money, he had the necessary qualifications to gain acceptance, he might become a member of one of the national institutions that existed to promote engineering and chemistry, thus being able to participate in lectures and discussions and the 'camaraderie' which such membership bestows. In the field of engineering, two national bodies were in existence in 1851, the Institution of Civil Engineers, founded in 1818, and the Institution of Mechanical Engineers, dating from 1847. For chemistry, there was the Chemical Society of London, established in 1841. All these groups included in their programmes a certain amount of material relevant to the metallurgist. The 60 years from 1851 saw the foundation of large numbers of societies and associations, some local and others national. The most relevant of the national bodies are listed in Table 8.1.

Britain's premier scientific group, the Royal Society of London, had already existed for nearly two centuries by the 1850s. Among the very first experiments recorded in 1661 had been 'a metallurgical series relating to the weight of lead increased in the fire ... at the assay office in the Tower',⁽¹⁾ while in 1662 and 1664 'the Royal Society discussed the possibility of investigating the making of steel' and enquired 'about methods of tempering steel ... (which) came up against the barrier of trade secrecy'.⁽²⁾ Despite this early concern shown for metals, the society's influence on metallurgical development before 1850 had been insignificant, and subsequently it remained only small. Through its Governmental mandate, in the opening years of the present century it influenced the setting up of the National Physical Laboratory which developed a strong centre of metallurgical research, and in later years it made funds available for research by means of fellowships. A number of people prominent in metallurgy, including academics, have been Fellows of the Royal Society.

Certainly during the nineteenth century, a more fruitful source of help in development of the subject was the British Association for the Advancement of Science; established at York in 1831, this had a policy of visiting different district centres for successive meetings, so stimulating interest in the various

(1) ROBERTS-AUSTEN, W.C., 'Metallurgy in its relation to chemical science. Introductory lecture to the course of metallurgy at the Royal School of Mines, session 1880-81'. In SMITH, S.W., Roberts-Austen, a record of his work, (London: Griffin, 1914), 86.

(2) FLINN, M.W. and BIRCH, A., 'The English steel industry before 1856 ...'. Yorks.Bull., vol.6 (Sep. 1954), 165.

Table 8.1. The chief national scientific, technical, and engineering bodies appropriate for promotion of metallurgical instruction

Those bodies whose concern with metallurgy was predominant are underlined

Name of Group	Foundation Date
Society for the Encouragement of Arts, Manufactures and Commerce	1754
Institution of Civil Engineers	1818
British Association for the Advancement of Science	1831
Chemical Society of London	1841
Institution of Mechanical Engineers	1847
<u>Iron and Steel Institute</u>	1869
Institute of Chemistry of Great Britain and Ireland	1877
Society of Chemical Industry	1881
Institution of Mining and Metallurgy	1892
Faraday Society	1903
<u>Institute of British Foundrymen</u>	1904
<u>Institute of Metals</u>	1908
<u>Institution of Welding Engineers/Institute of Welding</u>	1923/1935
<u>Institution of Metallurgists</u>	1945

regions of the country. The first meeting of the British Association in Newcastle-upon-Tyne had been held in 1838, and further meetings in Newcastle followed in 1863, 1889, 1916 and 1949. Around 1844, the British Association had supported an investigation into features of the iron blast furnace; carried out by the German Professor Bunsen of Marburg and the young Scottish chemist Lyon Playfair, the investigation was reported to the association in 1845.⁽³⁾

(3) BUNSEN, Professor R.W., and PLAYFAIR, Lyon, 'Report of the gases evolved from iron furnaces with reference to the theory of the smelting of iron'. Rpt. 15th meeting of Brit.Assocn., Cambridge, 1845, (London: John Murray, 1846), 142-186.

Of greater long-term significance was the metallurgical process described to the Cheltenham meeting of the British Association in 1856, for this was the fateful occasion on which Henry Bessemer was induced to lay out the details of his new technique for steelmaking, which was to have a profound effect upon world economics. In 1867, the reports published by the British Association and occasioned by the Paris Exhibition of that year included one by I. Lowthian Bell entitled 'The present state of ^{the} manufacture of iron in Great Britain and its position as compared with that of some other countries'. Twenty years later, in 1889, the association took steps to introduce an element of rational standardisation into the analysis of steel by preparing a series of alloys varying in composition; these were then analysed by prominent authorities, and samples made available 'for anyone who wished to check his own manipulation'. In 1920, these standards were still available.⁽⁴⁾ More recently, in 1952 an approach was to be made to the British Association by various British metallurgical groups who urged the creation of a subsection for metallurgy at the 1953 meeting, promising that several metallurgical papers would ensue.⁽⁵⁾ Besides the publication and discussion of papers on metallurgical topics, another relevant feature of the British Association's meetings was the compilation by local writers of handbooks containing particulars of the region. These books included descriptive reviews of metallurgical industry: although not deep, they nonetheless afforded useful accounts, for example, of North-eastern lead metallurgy and iron-and-steel making in 1863, and of the Glasgow district's iron-and-steel industry in 1901.

The Society for the Encouragement of Arts, Manufactures and Commerce had been founded in 1754. Almost a century later, through the initiative of a small group of its members, it became largely responsible for the mounting of the Great Exhibition of 1851. Occasionally, its meetings promoted metallurgical knowledge, for instance by some of its Cantor lectures. Thus, Professor W.C. Roberts-Austen, ARSM, of the Royal Mint and the Royal School of Mines, in 1884 delivered Cantor lectures on 'Alloys used for coinage'; evidently these were well received for in 1888 and again in 1893 he returned to give further lectures

(4) STEAD, J.E., 'Presidential address'. Jrnl.Iron Steel Inst., vol.101 (1920), no.1, 86.

(5) ANON., 'British Association'. Bull.Instn.Metallurgists, vol.4, no.2 (May 1953), 22.

on alloys. In 1895 the Cantor lectures were delivered by an American, James Douglas, who spoke on copper smelting. The subject of copper recurred nearly a quarter of a century later, when Professor H.C.H. Carpenter chose as his title 'Progress of the metallurgy of copper'. In 1950 aluminium was thoroughly surveyed by Dr. Colin J. Smithells, director of research for the British Aluminium Company, in his series of 'Three Cantor lectures on the manufacture, properties and applications of aluminium and its alloys'.⁽⁶⁾ In 1879 the meetings of the Society, and its Journal, were the setting for an exposition and discussion on the use and value of Bessemer's converting process applied to copper smelting;⁽⁷⁾ within a few years, extracts from the paper had been copied in extenso in at least one American textbook on copper, and the method proposed was being put into commercial use in Europe and the USA. It soon became standard smelting procedure. In connexion with the Paris Exhibition of 1878, the Society of Arts sponsored and published a set of 'artisan reports' which included a section on 'mining and metallurgy'.⁽⁸⁾ In 1868, by means of a competition, and again in 1916, the society sought to stimulate improvements in zinc smelting. The latter attempt resulted in the publication of two substantial reviews of the subject, the winning entry being printed in the Journal, with its closest rival subsequently appearing in book form under the title 'The zinc industry'.⁽⁹⁾

Following the 1851 exhibition the Society of Arts organised a series of lectures to review its results: these included one on 'The ironmaking resources of the United Kingdom'.⁽¹⁰⁾ Again, after the 1867 Paris Exhibition the society arranged a conference on the subject of 'scientific and industrial education' which took place at much the same time that, with the object of examining a closely-similar field, the Select Committee of the House of Commons was set up under the chairmanship of Bernhard Samuelson.

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- (6) SMITHELLS, COLIN J., 'Three Cantor lectures on the manufacture, properties and applications of aluminium and its alloys'. Jrnl.Royal Soc.Arts, vol.98 (25 Aug.1950), 822-863.
- (7) HOLLWAY, John, 'A new application of a process of rapid oxidation, by which sulphides are utilised for fuel'. Jrnl.Soc.Arts, (14 Feb. 1879), 248-263.
- (8) SOCIETY OF ARTS, Artisan reports on the Paris universal exhibition of 1878. (London: Sampson Low, 1879), 664pp.
- (9) SMITH, E.A., The zinc industry. (London: Longmans, Green, 1918), 218 pp.
- (10) SCRIVENOR, Harry, History of the iron trade (London: Longman, etc., 2nd edn., 1854), 301ff, fn.

Early in the 1870s the Society of Arts was instrumental in introducing the first British technological examinations, to complement those in science sponsored by the Government's Department of Science and Art. It is significant that J.F.D. Donnelly, of the Science and Art Department, was a member of the Society of Arts and originator of a proposal considered by the society's council in 1872 that it should establish such examinations. The society's object was to help to improve the technical education of artisans, and a condition of award of a certificate was that candidates should pass certain qualifying subjects of the Science and Art Department. Among the five subjects of the first examinations held in 1873 was 'steel manufacture' but, not surprisingly, the number of candidates coming forward for the examinations as a whole was only small in the first few years. One limiting factor was that 'no payments were offered to teachers nor was any instruction provided, and ... consequently all the candidates were self-taught'. However, for the year 1878 the Clothworkers' Company offered a grant of up to £250 to enable the Society of Arts to pay teachers a capitation grant and so encourage classes for instruction.⁽¹¹⁾ For the year 1879 arrangements were made for the society's pioneering technological examinations to be handled by the new City and Guilds of London Institute for the Advancement of Technical Education.

The London companies, or guilds, each of which was confined to a specific occupation or trade, had originated in mediaeval times to foster the social, spiritual, and material needs of their members; these needs originally included training. By the middle of the nineteenth century, however, many of the guilds persisted only as social bodies, retaining their names, ceremonies, and accumulated wealth, but not requiring technical qualifications as conditions of membership. In all there were 81 guilds existing in London: those concerned with the working of metals included the armourers and brasiers, blacksmiths, bladesmiths, cutlers, farriers, goldsmiths, gunmakers, ironmongers, pewterers, plumbers, spurriers and tinplate workers. Although not primarily concerned with metals, the Clothworkers' Company and the Drapers' Company also merit mention here, as both became leading benefactors to technical education.

(11) MILLIS, C.T. Technical education its development and aims.
(London: Edward Arnold, 1925), 59.

During the 1870s there arose considerable public discontent over the supposed great wealth of the London guilds and their alleged ineffectiveness in carrying on the earlier traditions of training. Alarmed by this public criticism and animosity, in July 1876 some of the companies called a meeting at which representatives adopted a resolution stating the desirability:⁽¹²⁾

'that the attention of the Livery Companies be directed to the promotion of Education not only in the Metropolis but throughout the country, and especially to technical education, with the view of educating young artizans and others in the scientific and artistic branches of their trades.'

Some considered greater results might be achieved by the companies working in combination rather than separately, and in 1877 a provisional committee of certain of the guilds was formed to prepare a national scheme of technical education. Among those invited by the committee to submit recommendations were Colonel Donnelly of the Science and Art Department, Sir William Armstrong FRS, the engineer and armaments salesman, and Professor T. Huxley FRS, of the Royal School of Mines. In 1878 a conference of 23 companies founded the City and Guilds of London Institute for the Advancement of Technical Education,⁽¹³⁾ and in the following year the scheme resulting from the committee's deliberations was adopted. In expressing its view of what was desirable by way of instruction, the committee used iron as one illustration:⁽¹⁴⁾

'... it would be unwise to endeavour to improve ... manufacture by instructing a puddler how to handle his tools in a superior manner, or the blast furnace man how to manipulate his furnace; but on the other hand your Executive Committee think it would be of great utility to give to such men (and especially to the managers of ironworks) the scientific instruction which will enable them to know why it is that occasionally, in spite of manual dexterity, and in spite of attention, the puddle-bar is bad or the pig iron

(12) MILLIS, C.T., op.cit., 54.

(13) HEATH, H. Frank and HETHERINGTON, A.L., Industrial research and development in the United Kingdom a survey. (London: Faber, 1946), 307.

(14) MILLIS, C.T., op.cit., 56-57.

'is unsaleable ... The application of the science of chemistry to the manufacture of iron affords this knowledge.'

However, not all of the London guilds were prepared to participate in the corporate scheme; the Cutlers' Company, for example, reported in 1878 that it would not join in the combined action suggested by the committee on the grounds that the general scheme of education proposed would be of little benefit to cutlers and, moreover, 'would be somewhat calculated to interfere with perfect freedom of action on the part of the Cutlers' Company'. Accordingly, the company reportedly took action on its own to encourage production of superior articles of cutlery and promote the interests of the trade.⁽¹⁵⁾

At the end of 1879 Professor Thomas Huxley took the opportunity of a discussion on 'apprenticeship' at the Society of Arts to draw attention to the 'enormous wealth' possessed by the companies in the City of London who were 'the inheritors of the property and traditions of the old guilds': this wealth was intended for technical education. He said that the people of the country should insist upon the money being used for that purpose and, 'as far as London was concerned ... it would be an utter scandal and robbery if one shilling (£0.05) were asked for out of the general revenue to pay for technical education.'⁽¹⁶⁾ The editor of the journal Iron was delighted to make capital out of this statement, under the heading 'The plunder of the poor', pointing out that the revenue of the Corporation of London amounted to £600 000 a year, while the income of the livery companies was at least £1 million and might exceed £2 million; considerable sums could therefore be spent on the proposed education without hardship.⁽¹⁷⁾

In the event, the proposals for joint initiative on technical education went ahead, and in the 65-year period up to 1945 the supporting companies gave the City and Guilds of London Institute for the Advancement of Technical Education about £1.3 million. The Goldsmiths' Company was the largest single

(15) ANON., 'Technical education'. Iron, vol.12 (16 Nov. 1878), 622.

(16) MILLIS, C.T., op.cit., 54.

(17) ANON., 'The plunder of the Poor'. Iron, vol.14 (19 Dec. 1879), 775.

contributor with £270 000, while the Skinners', for instance, after giving £3000 in 1878 towards the establishment of the institute, contributed altogether some £120 000.⁽¹⁸⁾ A commentator in the early 1880s considered that⁽¹⁹⁾

'If it is efficiently conducted, the City and Guilds of London Institute will probably become the chief authority for technical education in England. ... it will render splendid service in the work of reviving, controlling, and improving industry, and allying it more closely than has hitherto been the case with science and art.'

One of the tasks undertaken by the City and Guilds Institute was organisation of a national examination system intended to stimulate technical instruction among artisans. In fact, the institute took over the examination system in technological subjects fostered by the Society of Arts for the previous half-dozen years. The numbers and scope expanded rapidly: in 1880 there were twenty-four subjects and 800 candidates; by 1900 there were 64 subjects and 14 000 entries.⁽²⁰⁾ The 'steel manufacture' of the Society of Arts became 'iron and steel manufacture', attracting 83 entries in 1880, 145 in 1890, and 126 in 1900. Only two years later there was a doubling of the number to 253 for this subject, but decline then set in, so that by 1929 the number had fallen to only 61.⁽²¹⁾ 'Mechanical preparation of ores' was an allied subject introduced in 1880 by the City and Guilds' Institute,⁽²²⁾ although, in common with 'electro-metallurgy', examinations in it were said to have been originally established by the Society of Arts.⁽²³⁾

The fact that the City and Guilds' Institute assumed responsibility for the payment of small sums to teachers presenting successful examination candidates

(18) HEATH, H. Frank and HETHERINGTON, A.L., op.cit., 307; 309,310.

(19) EDWARDS, F.W., Technical Education: its rise and progress. (London: Longmans, Green, 1885), 32.

(20) ARGLES, M., South Kensington to Robbins. (London: Longmans, 1964), 23.

(21) MUSGRAVE, P.W., Technical change the labour force and education. (Oxford, etc.: Pergamon, 1967), 94 and 158; quoting figures communicated by F.E. Foden of Loughborough College of Commerce.

(22) Iron, vol.15 (13 Feb. 1880), 114.

(23) ROYAL COMMISSIONERS ON TECHNICAL INSTRUCTION, Second report vol.1, Parl.papers vol.29 (1884), Cd. 3981, 403.

led in some places to the running of instructional classes. At Elswick on Tyneside, where there was a school associated with Sir William Armstrong's engineering works, around 1880, classes were held in the metallurgy of iron and steel in conjunction with the institute. Also in the years before 1900 classes in this subject were offered in Middlesbrough.

Classes were also encouraged by grants: early in 1880, the committee of the City and Guilds' Institute recommended the grant of £100 a year for three years to the Miners' Association of Cornwall and Devon to aid the extension of classes for working miners.⁽²⁴⁾ In like manner, grants of £300 a year for five years were provided for the new technical school in Sheffield.⁽²⁵⁾ A specific item of the 1879 proposals included financial support to the extent of £400 a year, for four professorships at existing London colleges: those of chemical technology and mechanical technology at University College, and chairs of practical fine art and metallurgy at King's College. To the chair of metallurgy was appointed A.K. Huntington, ARSM, who was to occupy it for 40 years; on his retirement in 1919, it lapsed.

Throughout the 75-year period from the mid 1870s to 1950, the examinations in aspects of metallurgy started by the Society of Arts and continued by the City and Guilds' Institute afforded the ambitious man, unable to attend full-time studies yet wishing to learn something of the subject, with means to attain his object. On the wider front the formation in Britain of 'technical colleges' and their courses was greatly assisted by the valuable incentive provided by the institute's schemes.

The City and Guilds' examinations could be taken at a number of local centres where appropriate courses were provided. They were mainly of 'craft' level; that is they aimed at standards achievable by a substantial proportion of industrial employees. Until the 1930s there were three levels of examination: grade 1, grade 2, and final. The highest qualification attainable by the system was the Full Technological Certificate, originally

(24) Iron, vol.15 (27 Feb. 1880), 153.

(25) ROYAL COMMISSION ON THE DEPRESSION OF TRADE AND INDUSTRY, Second report (minutes of evidence and appendix part 1). (London: HMSO, 1886), 79; evidence of Charles Belk, the master cutler of Sheffield.

introduced by the Society of Arts 'to mark the achievement of a candidate who qualified in certain Science Department subjects as a preliminary and also as a bona fide practitioner of the trade in which he was examined'.⁽²⁶⁾

Nonetheless, the examinations system had its ups and downs, suffering serious decline in popularity in some technical subjects in the years before 1930. Some of this decline resulted from the ill-advised attempt of the Board of Education to promote substitute examinations supplied by the local colleges for those of the established City and Guilds' system. As part of this attempt, in 1920 the Board of Education requested that in England and Wales the lower-grade examinations in iron-and-steel manufacture be stopped. However, local colleges were unwilling to come forward, and the lower-grade examinations, together comprising an 'intermediate' level, were re-started in the session 1933-34.

Until 1930 the advanced-level metallurgy papers were in 'iron and steel', 'non-ferrous metallurgy (extraction and working)', and 'electrometallurgy', but the small numbers of students availing themselves of the metallurgy scheme in the late 1920s prompted serious reappraisal by the City and Guilds' metallurgy advisory committee. For many of the years between 1931 and 1950 the principal of the Constantine Technical College in Middlesbrough was among the members of this committee, which was stated to be 'composed of experts in the subject, nominated by scientific and technical societies and educational bodies'.⁽²⁷⁾ In the mid 1930s this committee sat under the chairmanship of Mr. George Patchin, ARSM, principal of the Sir John Cass Technical Institute. The aim of the reappraisal was to provide a series of examinations that would give incentive to an integrated programme of study, conveniently spread over five sessions of three evenings weekly. In this revised scheme, emphasis was placed upon a foundation of fundamental sciences, supplemented by some features of 'general metallurgy', for which intermediate examinations were provided after the third year. The final-grade examination, intended to be taken after the fifth year of study, was to consist of two papers, one

(26) FODEN, F.E., 'Sir Philip Magnus and the City and Guilds of London Institute'. Vocat.Aspect, vol.14 (Autumn 1962), 110fn.

(27) ANON., 'Metallurgy syllabuses and examinations'. The Engineer, vol. 159 (28 June 1935), 680.

concerned with 'physical metallurgy', by which was meant 'metallography, pyrometry, heat treatment, physical testing and microscopic examination', and the other with some specialised branch. The choices available for the specialised paper were 'iron and steel', 'non-ferrous metals and alloys (extraction)', 'non-ferrous metals and alloys (manufacture)', 'electro-thermal processes', and 'electrolytic extraction and refining'.⁽²⁸⁾ The inclusion of a substantial section on 'physical metallurgy' was a reflection of the considerable growth of knowledge that had taken place since the turn of the century. The re-structuring, with greater emphasis on a secure foundation of science and mathematics, can be seen to have been initiated by the growing movement to provide national certificate schemes in British technical education, although such a scheme for metallurgy was not introduced until after 1945.

The advisory committee's first revised scheme was published in readiness for the 1933-34 session, with approval by the Board of Education. In the event the examination results in 1934 were poor, with a pass rate at the intermediate level of 48 per cent. and at the final level of less than 20 per cent.⁽²⁹⁾ As a result, the metallurgy advisory committee approached the problems more critically in a determined attempt to produce an improved set of syllabuses. Professor J.H. Andrew of the University of Sheffield, and Assistant Professor L. Taverner, ARSM, of the University College of Swansea, were the chief architects of the fresh proposals, outlined above. A later commentator remarked that these proposals 'were to have profound effects upon future development of metallurgy courses. It was the first time that deep educational thought had really permeated ...'.⁽³⁰⁾

In 1938 the deliberations of the metallurgy advisory committee were stimulated by the intimation of the superintendent of the City and Guilds' Institute that, because of expense, examinations in such a poorly-supported subject as metallurgy might be discontinued. Moreover, attention was drawn to the possible revival of a national certificate scheme for metallurgy. The committee therefore sought to cater both for 'the artisan' as before, and

(28) ANON., loc.cit.

(29) DUNNING, J., 'An appraisal of national certificate courses in metallurgy, on Teesside 1957-1963'. Unpublished M.Ed. thesis, University of Durham (1967), 8-14.

(30) DUNNING, J., op.cit., 21.

'the executive': syllabuses were devised for two sets of examinations in place of one, the course at final level for executives being entitled 'principles and practice of metallurgical operation' and containing six metallurgical topics of which examinations in four had to be passed for an advanced certificate and five for a full technological certificate.⁽³¹⁾ When, around 1944, renewed demand for a national certificate scheme did arise, attempts were made to integrate the pattern of courses and examinations established in the subject by the City and Guilds' Institute with the other elements implicit in the national certificate system. However, opposition from various quarters prevented this compromise from becoming reality with the result that when national certificates in metallurgy were introduced they were independent of the City and Guilds' Institute and tended to draw students away from its courses and examinations, even though the syllabuses used by colleges for the new qualification owed much to the institute. Like the revised City and Guilds' syllabus, these national certificate schemes involved five years of study, with an intermediate step after the third year, that is ordinary national certificate, and they required the student to perform some practical laboratory work during his course, something which was lacking from the earlier City and Guilds' requirements.

In 1937 there were 56 entries for the City and Guilds' intermediate examinations in metallurgy, and 54 for the final examinations in iron and steel. These entries came from eighteen centres: Crewe, Shotton, Workington, Consett, Swansea, Barrow, Scunthorpe, Chelsea, Sir John Cass Institute, Newcastle, Stoke, Wednesbury, Birmingham, Coventry, Bradford, Rotherham, Edinburgh and Glasgow.⁽³²⁾ Two years later, in 1939, the number of candidates for the intermediate examinations rose to more than 100, and in 1941 it reached 200. During the war years 1940 - 1944 the entries for the final examinations showed a corresponding increase, to more than 120 in 1944. In the same period the number of centres preparing candidates rose to thirty-three.⁽³³⁾

Besides contributing to the City and Guilds' Institute, a number of the

(31) DUNNING, J., op.cit., 26, 27; 55.

(32) DUNNING, J., op.cit., 23.

(33) DUNNING, J., op.cit., 39.

London livery companies individually provided support for developments in technical education. To augment the £400 a year granted by the institute to King's College London for a professorship of metallurgy, the Drapers' Company gave £500 to equip the metallurgical laboratory there. Even before the City and Guilds' Institute had begun its activities in 1879 or had become incorporated under the Company Acts in the following year, the Clothworkers' Company had given funds to the Society of Arts to enable it to adopt for certain technological subjects the system of payment on results, thereby encouraging teachers and regular classes. Later, the Drapers' Company provided the applied science laboratories for the University of Sheffield, while the Ironmongers' Company 'founded a fellowship of £500 and two research scholarships of £150 each at Sheffield University for cold working of steel and other ferrous metals.'⁽³⁴⁾ The Armourers and Brasiers claimed, in the years before 1940, to be 'active and generous benefactors by scholarships for engineering (including aeronautics) and metallurgical research'. They granted £100 a year to Sheffield University and co-operated with the Sheffield trades' societies and the Master Cutler in granting prizes and diplomas for new ideas to operatives in iron, steel, and allied industries. The company also gave a two-year bursary to an apprentice in metal works in Birmingham. The Cutlers' Company maintained scholarships and exhibitions at Oxford, Cambridge, London and Sheffield universities, while the Tin Plate Workers and Wire Workers awarded a bursary at Sheffield University. The Founders' Company awarded two annual fellowships of £250 each for postgraduate study as well as three three-year scholarships of £40 a year in engineering at King's College London. Dr. W. Hume-Rothery, FRS, was awarded an Armourers and Brasiers' Company research fellowship during 1929-32, early in his long career of investigation and teaching which was to lead to his appointment as first professor of metallurgy in the University of Oxford.

The Plumbers' Company supported classes in its subject, at any rate in the closing decades of the nineteenth century. Thus, in 1889 the Durham College of Science in Newcastle included classes in plumbing associated with

(34) HEATH, H. Frank and HETHERINGTON, A.L., op.cit., 308-309.

(35) HEATH, H. Frank and HETHERINGTON, A.L., op.cit., 308-310 and 351-355.

the London company, while at much the same time plumbing classes were available at other places, such as Croydon Polytechnic. In 1903 the company produced a set of diagrams 'for the use of classes of technical instruction for plumbers'.⁽³⁶⁾

The Worshipful Company of Goldsmiths, one of the wealthiest London livery companies and one which continued to exercise its right of testing and stamping gold and silver articles, has been the single most conspicuous contributor to metallurgical instruction. In 1914 the company presented the Sir John Cass Institute with equipment for a testing laboratory. A few years before this, in 1908, money to support a metallurgical readership was given to the University of Cambridge; later, in 1932, the endowment was increased in value so that a chair could be established, the Goldsmith's Professorship in Metallurgy. From time to time money was also provided for the building of new laboratories, and over an extended period funds were made available for promoting research in matters affecting the gold and silver industries.

The groups so far considered can be regarded as chiefly composed of disinterested people concerned with the promotion of technical education as a whole rather than with only a particular sector of the field. By contrast, considerable influence has also come from engineering and technical societies for specific developments, including those in metallurgy. The senior engineering society in Britain, the Institution of Civil Engineers, imposed restrictions upon membership which, throughout the period under review, resulted in such membership's being regarded as a worthwhile professional qualification. In the 1850s it is doubtful whether more than a dozen of those practising metallurgy would have been considered eligible for membership of the institution. Occasionally, its Proceedings contained papers of metallurgical interest, such as 'The manufacture of steel' and 'On Bessemer steel rails', which were both published in 1874-75. Bernhard Samuelson, soon after his election to membership, was awarded the institution's Telford Medal for his 'Description of two blast furnaces erected in 1870 at Newport, near Middlesbrough'.⁽³⁷⁾

(36) PLUMBERS' COMPANY, 'The Plumbers' Company's diagrams for the use of classes of technical instruction for plumbers'.
(London, 1903).

(37) SAMUELSON, B., 'Description of two blast furnaces erected in 1870 at Newport, near Middlesbrough'. Mins.Proc.Instn.Civil Engrs., vol.32 (1870-71), pt.2, 329-348 plus 3 plates.

I. Lowthian Bell not only became a member but served as president. In the 1920s Professor H.C.H. Carpenter, FRS, of the Royal School of Mines, delivered to the institution a lecture entitled 'Some recent services of metallurgy to engineering', while in 1945 the survey was updated by another lecture, 'Some developments in ferrous metallurgy'.⁽³⁸⁾

The Institution of Civil Engineers showed some practical concern for engineering education: in 1868 an 'exhaustive inquiry' was made into the conditions and systems of such education existing in Britain and in foreign countries, the results being published by the institution in 1870. At five of the seven centres in this country which purported to provide 'an engineering education' there was a single teacher and no laboratory.^(39A) Twenty years later another statement was published, 'dealing fully with the facilities for engineering education afforded ... by the engineering schools of universities and colleges in the British Dominions'. During the 1890s the institution established a system of examinations for students and associate members.^(39B) Shortly after the opening of the new century, in collaboration with other engineering societies, the institution was responsible for preparing a report on 'education and training of engineers'. The Iron and Steel Institute was included among the bodies represented, and 47 iron-and-steel manufacturers were among the total of 676 organisations and individuals approached for views. Only one third of the iron-and-steel makers replied to the questionnaire, compared with an overall response of almost 40 per cent.⁽⁴⁰⁾ The report resulted from the work of a committee which sat under the chairmanship of Sir William H. White, formerly the Admiralty's chief constructor; in 1908 he was to become the first president of the new Institute of Metals. Although in Britain throughout the century 1851 - 1950 for several reasons 'the metallurgist' was widely regarded as definitely not 'an engineer', it is appropriate to review briefly the chief recommendations 'in respect of engineering education' which were made by the committee; these were adopted by the council of the Institution

(38) CARPENTER, H.C.H., 'Some recent services of metallurgy to engineering' (the James Forrest lecture, 1927). Mins.Proc.Instn.Civil Engrs., vol.224 (1926-27), pt.2, 291-341.

SYKES, C., 'Some developments in ferrous metallurgy' (reprint of 1945 James Forrest Lecture). Jrnl.Instn.Civil Eng., vol.24 (Oct. 1945), 315-347.

(39A) ARMYTAGE, W.H.G., A social history of engineering. (London: Faber and Faber, 3rd edn.1970), 235.

(39B) INSTITUTION OF CIVIL ENGINEERS, 'Education and training of engineers. Report of a committee appointed by the council ... on November 24th, 1903'. Reproduced in Trans.Instn.Mining Engrs., vol.30 (1905-06), 465-486.

(40) INSTITUTION OF CIVIL ENGINEERS. op.cit., 192.

of Civil Engineers in 1906. The report recommended that 'the average boy' should leave school at about seventeen years of age. The committee was 'unanimous in the opinion that engineering training must include several years of practical work, as well as a proper academic training.' Practical training should be divided into two sections, with one part, a preliminary year, spent in mechanical-engineering workshops. Some of the training should be obtained in drawing offices, and altogether a total of four years' practical training was favoured, although three years, or even less for exceptional ability, would be appropriate where college training was completed before undertaking practical training. As far as formal academic tuition was concerned, a period of three college sessions was advised 'for the average student', provided he was well prepared, but it was added that students 'who desire to follow up the science of their profession' might profitably add a fourth year at college. It was pointed out that 'a sound and extensive knowledge of mathematics is necessary in all branches of engineering'.⁽⁴¹⁾

Several other sections of the recommendations of the Institution of Civil Engineers' joint committee remain of relevance three quarters of a century later. For instance the committee advised that, wherever feasible, first-year college work should be common for all engineering students. Again, the committee recommended that mathematics' teaching should be integrated with the engineering instruction, and that 'teachers of pure mathematics ... in dealing with the students during their common course of study, should be well-informed as to the applications of mathematics in engineering'. The report commented that 'instruction in testing materials ... and in the principles underlying metallurgical processes ... incidental to the branch of engineering in which the student proposes to specialize, should be included in the college course.'⁽⁴²⁾ Moreover, facilities for, and organisation of, postgraduate work by engineering students in universities and higher technical institutions should be considerably increased. It was considered that the influence of the research students and the products of their researches would be 'highly beneficial' to younger students and advantageous to industry. Finally, the committee recognised what was at the

(41) INSTITUTION OF CIVIL ENGINEERS, op.cit., 494-498.

(42) INSTITUTION OF CIVIL ENGINEERS, op.cit., 498.

time, and was to remain for many years, one of the biggest obstacles to better qualification by the individual: 'the sympathetic assistance of employers is essential to improvement in engineering education and training.'⁽⁴³⁾ Some years later, around 1911, the Institution of Civil Engineers played a large part in the organisation of a conference on engineering education.⁽⁴⁴⁾

Like the Institution of Civil Engineers, the younger Institution of Mechanical Engineers, founded only a few years before 1851, sought to restrict membership to those showing evidence of certain standards of engineering competence. Perhaps by the nature of the interests of members of the two institutions, the Mechanical Engineers provided greater kinship for metallurgists. In the thirty-year period up to 1881 the Proceedings of the Institution of Mechanical Engineers contained a dozen papers on aspects of steel, ranging from 'Manufacture of the Uchatius cast steel' of 1858, which described a process carried on in Newcastle-upon-Tyne, to 'Iron and steel for ships' of 1881, which dealt with the mechanical behaviour of the materials. Because of the institution's interest in materials it appointed about 1878 a 'committee on the hardening, tempering, and annealing of steel'. Among the members of this were Mr. (later Dr., and Sir) William Anderson, the director-general of the Royal Ordnance Factories at Woolwich, who was chairman, Professor F.A. Abel, FRS, a former student of the College of Chemistry in Hanover Square in 1845 and chemist to the War Office, and W. Chandler Roberts, ARSM, FRS, who became professor of metallurgy at the Royal School of Mines shortly afterwards. The first report of this committee, compiled in 1879, was published in 1881, while another, describing the condition in which carbon exists in steel, appeared in 1885.

Again, in the early part of 1890, on the recommendation of Dr. Anderson, the council of the Institution of Mechanical Engineers appointed a committee, the Alloys Research Committee, with the object of furthering investigations which Professor W.C. Roberts-Austen (as he then styled himself) had already made into the effects of small admixtures of impurities on the mechanical properties of metals. During the ten years which followed, five reports on

(43) INSTITUTION OF CIVIL ENGINEERS, op.cit., 499.

(44) ARMYTAGE, W.H.G., op.cit., 247.

the work were presented to the institution.⁽⁴⁵⁾ This metallurgical research work stimulated by the Institution of Mechanical Engineers was to have far-ranging results. Until 1902 most of it was done at the Royal Mint, where a succession of Associates of the Royal School of Mines obtained excellent postgraduate experience, at the same time laying the foundations for much twentieth-century knowledge of alloys and the techniques for their investigation. The first report, for instance, presented in October 1891, drew attention to the recently-discovered Le Chatelier pyrometer as a useful tool for such work. Those metallurgists associated with Professor Roberts-Austen included: Henry C. Jenkins, afterwards instructor at the Royal School of Mines and Government metallurgist in Victoria; Alfred Stansfield, from 1901 professor of metallurgy at the McGill University, Montreal; William H. Merrett, subsequently assistant professor of metallurgy at the Royal School of Mines; A.J. Brett, manager of the Crown Mines, Johannesburg;⁽⁴⁶⁾ and S.W. Smith, assayer at the Royal Mint.⁽⁴⁷⁾ After 1902, coinciding with the death of Roberts-Austen, the investigations were transferred to the newly-opened National Physical Laboratory, thereby providing encouragement for metallurgical research there from its early years.

The Institution of Mechanical Engineers' sponsorship of work on alloys in the quarter century from 1879 advanced and broadened the subject of metallurgy and did much to bring about an appreciation of the possibilities of 'research'. However, not all of the work of the 'metallurgist' falls within the scope of 'engineering', and for many purposes and many people, especially in the period before 1930, metallurgy was considered to be a branch of chemistry. It was therefore natural that some metallurgists should look for technical stimulation and fresh information to the pages of chemical periodicals and the meetings of chemical societies. The earliest of such groups, exclusively devoted to the science of chemistry, had been formed in 1841 as the Chemical Society of London; its aims were 'the general advancement of chemical science, by the discussion and publication of new discoveries, and

(45) SMITH, S.W., Roberts-Austen a record of his work.
(London: Griffin, 1914), 132.

(46) SMITH, S.W., op.cit., 144.

(47) HAUGHTON, J.L., 'Metallurgical research in government laboratories'.
Proc.(First) Empire Mining Metall.Congress (London 1924),
part 5, non-ferrous metallurgy. (London, 1925), 107.

the interchange of valuable information respecting them.'⁽⁴⁸⁾ In 1877 another group, the Institute of Chemistry of Great Britain and Ireland, was established to protect the standing of professional chemists, membership being made conditional upon fulfilment of certain criteria. In the period up to 1945, when few qualifications in metallurgy itself were available, membership of the Institute of Chemists was sought as a recognition of technical competence by an appreciable proportion of those working in metallurgical industries.

Only four years after the Institute of Chemistry had come into being there was formed, in 1881, yet another body, the Society of Chemical Industry; this aimed to take all manufacturing chemistry in its purview. The first president was Sir Henry Roscoe of Manchester, and there was considerable fraternisation between it and the other chemical groups. At first a section of the society's Journal was set aside for metallurgy; subsequently, 'electro-metallurgy' was segregated. Professor A.K. Huntington, ARSM, of King's College, London, addressing the Institute of Metals in 1913, observed that 'there can be no doubt that the Society of Chemical Industry has done good work in the field our institute covers, and we should be grateful to it'.⁽⁴⁹⁾ Huntington had been persuaded by Sir Frederick Abel to contribute two short papers to the first annual meeting of the society, held in Manchester: the 'Mexican amalgamation process for silver', and 'Nickel'. I. Lowthian Bell served as president of the society, and for his address discussed 'Smelting of iron ores considered chemically'. Papers read before sections of the society in the period 1896 - 1905 included about thirty having direct metallurgical relevance; these ranged from 'The dressing of minerals' and 'The manufacture of pig iron in India' to 'The physical and chemical properties of slags' and several dealing with gold extraction by cyanide solutions, a commercial technique which had originated in Scotland shortly before 1890.⁽⁵⁰⁾

(48) PILCHER, Richard B., The Institute of Chemistry of Great Britain and Ireland ... History of the Institute: 1877-1914.
(London: The Institute, 1914), 9.

(49) HUNTINGTON, A.K., 'Presidential address'. Jrnl.Inst.Metals, vol. 9 (1913), no. 1, 29.

(50) RENAULT, F.W. and others (eds.), 'List of papers read before sections of the society ... 1896-1905'.
Decennial index of the Journal of the Society of Chemical Industry vols. 15 to 24, 1896-1905,
(London: Vacher & Sons, 1908), 1-19.

The number of chemical societies, at least partly relevant to the metallurgist, was further increased in 1903 with the foundation of the Faraday Society, the scope of which originally embraced the topics of metallography and electric furnaces. In 1914 the society organised a 'general discussion' on 'the hardening of metals', followed in 1915 by one on 'the corrosion of metals', and in 1920 it held a meeting on 'basic slags: their production and utilization in agriculture'. Five years later the Faraday Society took the metallurgical initiative once again by arranging a London meeting on 'the physical chemistry of steel-making processes'. This was the first time the topic had been widely discussed and, according to a leading steel researcher in the 1970s, it provided 'the first stimulus to modern research on metallurgical reactions'.⁽⁵¹⁾ Nearly a quarter of a century onwards, the society was responsible for promoting another discussion meeting on much the same theme, but this time broadened to cover more than one metal: 'the physical chemistry of process metallurgy'. This event was held outside a big town, at Ashorne Hill in Warwickshire; it attracted 150 participants, and the material presented was to influence the thinking and actions of researchers during the following two or three decades.

With the exception of the London city guilds, all of the groups mentioned so far were national in character. It is true some held meetings in a succession of towns while others, such as the Society of Chemical Industry, organised a number of 'local meetings'. Besides these, several regional bodies have not only supported metallurgists at one time or another but have been the vehicle for appreciable encouragement of metallurgical instruction. In this category two regional societies important in their districts during the third quarter of the nineteenth century were the South Wales Institute of Engineers and the Cleveland Institution of Engineers. The former, founded at Cardiff in 1857, by the nature of its district was primarily devoted to matters relating to the coal industry, although it found room for ironmaking. By contrast, the Cleveland Institution of Engineers, formed in 1864, while concerned with technical developments in the iron industry, was also a forum for the delivery and discussion of papers on a wide range of engineering subjects. For the last forty years of the nineteenth century and the first twenty or thirty of the twentieth, the regular monthly meetings of the Cleveland

(51) TURKDOGAN, E.T., in PEHLKE, R.D. and others (eds.),
BOF steelmaking volume 2 theory. (New York: Iron Steel
 Soc. of AIME, 1975), 1.

Institution of Engineers must have been a major source of technical stimulus to those involved in the higher levels of the local iron-and-steel industry. Moreover, on a number of occasions presidents found opportunity in their addresses to stress the desirability of increased technical instruction; during the period 1910 - 1950, the institution influenced the creation of a technical college in Middlesbrough to serve industrial needs.

One further society to be considered is the Institution of Mining and Metallurgy. Unlike the other bodies reviewed, this was sufficiently concerned with metallurgy to be invited in the 1930s and 1940s by the Board of Education to participate with the Iron and Steel Institute and the Institute of Metals in discussions with the object of producing a national certificate scheme in metallurgy: in the second half of the 1940s it was a constituent of the Joint Committee on Metallurgical Education. Nonetheless, as its title suggests, this group's predominant concern was with mining, and it is partly for this reason that its impact upon metallurgical instruction was considerably less than might otherwise have been the case.

The idea of a body that would reflect the professional and technical interests of those engaged in metal mining and the associated metal production was mooted early in the 1880s at a meeting of a dozen Associates of the Royal School of Mines, but the suggestion was unsuccessful at the time; it took another ten years before it proved possible to achieve the desired object and there came into being what was soon styled 'the Institution of Mining and Metallurgy'. Among the factors providing inspiration for formation of the new society was the success of two bodies with more-or-less unrestricted membership: the Iron and Steel Institute, formed in 1869, and the American Institute of Mining Engineers, founded two years later, in 1871, in the USA. Despite its title, the interests of the American institute extended from mineral deposits to metal production, the word 'metallurgy' being added in 1919. Around 1880 several of the British regional societies concerned with mining lent support to formation of a national federated Institution of Mining Engineers. At this time too, London was fast becoming an important financial centre, the controlling capital of metal production undertaken with British money in far-distant parts of the world, for example tin in Malaya, copper in Australasia, and gold in South Africa, Western Australia and South India. Thus there appeared to be scope for a body which embraced this sector of industrial

endeavour. In an attempt to avoid conflict, on the one hand with the established mining institutes and on the other with the Iron and Steel Institute, the Institution of Mining and Metallurgy was careful to state that its objects included the advancement of 'the science and practice' of mining minerals other than coal, and the metallurgy of metals other than iron. Another object, and one pertinent to education, was 'to facilitate the acquisition and preservation of that knowledge which pertains to the profession of a mining engineer and metallurgist'. (52)

Like the Institution of Mining Engineers and the older Institutions of Civil and Mechanical Engineers, the Institution of Mining and Metallurgy sought to make itself a professional body, admitting to membership only those who could show evidence of what were at the time high academic standards, together with experience of responsible work. Two grades of corporate membership were created, 'members' and 'associate members'. There was, in addition, a class of 'student members'. This stipulation of certain standards for technical and ethical competence arose from the employment requirements of the London financial groups, which needed men to serve as managers or agents, representing their employers far away from headquarters. In this respect, the industry associated with the Institution of Mining and Metallurgy differed substantially from that related to the Iron and Steel Institute, where works' proprietors might be in direct and daily control of their enterprises, able to keep close check on the actions of their technical employees. However, by this careful delineation of its territory of interest, as well as by the substantial restriction of those eligible for membership, the institution handicapped itself, with the result that its sphere of influence remained limited throughout the period under review. Moreover, although its objects referred to 'the metallurgy of metals other than iron', the institution chose to confine its metallurgical field to the extraction of metals: it ignored those aspects relating to the properties, behaviour, and subsequent treatment of metals for effective use, an area which saw very great expansion during the first half of the twentieth century.

Not surprisingly, throughout the period up to 1950, the Institution of Mining and Metallurgy had close links with the Royal School of Mines. During

(52) ANON., Extraction and refining of the rarer metals (Procs. of a symposium ...). (London: Instn.Min.Metall., 1957), facing title page.

the first decade of the century it was instrumental in emphasising the importance to industry of the school to the Royal Commission on the future of the Royal College of Science and the Royal School of Mines, from whose recommendations the Imperial College of Science and Technology emerged. Again, in 1910-11, it successfully campaigned for subscriptions for equipping a 'Bessemer memorial laboratory' at the school. Conveniently situated for the London offices of companies with overseas interests, the extensive equipment in this building, besides serving the needs of students, was designed to provide commercial testing facilities in the capital. Many of the items were large enough for pilot-plant scale, and incidentally in succeeding years became increasingly extravagant to run.

In 1924, the year of the Empire Exhibition at Wembley, the institution was responsible for much of the organisation, at Wembley, of an 'empire mining and metallurgical congress'. Lasting for three or four days, this meeting proved to be the first of a series, at one time intended to be triennial and, under the changed name of the 'commonwealth mining and metallurgical congress', extending into the 1970s. The second congress was held in Canada in 1927, the third in South Africa in 1930, and the fourth again in Britain in 1949 after an interval of nearly twenty years. By their promotion of international improvements in the technology and economics of the mineral industries these congresses had some influence upon metallurgical instruction. In addition, the first one provided the occasion for a survey of British university facilities for such instruction. This was presented by Professor H.C.H. Carpenter of the Royal School of Mines and it formed one of the few publicly-recorded instances of interest in the topic to appear before 1937. (53)

Despite being based in London, by its nature the Institution of Mining and Metallurgy showed wide geographical spread in the subjects of its papers, which were presented for discussion at meetings and published in the regular Transactions. Within the institution, high standards of technical competence could be recognised by award of 'honorary membership', and of various medals and sums of money. Among these awards was one, the Arthur Claudet prize,

(53) CARPENTER, H.C.H., 'Metallurgical education of university rank in Great Britain'. Proc.(1st) Empire Mining Metall.Congress, London 1924, part 5, non-ferrous metallurgy, (London: 1925), 43-79.

directly intended to encourage papers by metallurgical students; until 1950, each year this prize was of ten guineas (£10.50). From 1902, merit in either a paper or in research presented by corporate members could be encouraged by award of the Consolidated Gold Fields of South Africa Limited gold medal and premium of forty guineas (£42.00). To mark distinguished service in accord with the institution's objects, 36 recipients were given its own gold medal in the half century to 1950. Of this number a minor but appreciable fraction was bestowed partially or wholly in recognition of advances in technical education, but only four or five related specifically to metallurgy: two or three before 1910, and one or two more in the 40 subsequent years. Clearly, metallurgical instruction did not feature prominently in the institution's council. Indeed, of the 50 presidents to hold office in the period from the institution's inception in 1892 to the year 1950, only three were full-time teachers of metallurgy: A.K. Huntington, ARSM, (1894-95), professor at King's College, London; William Gowland, ARSM, (1907-08), professor at the Royal School of Mines; and a subsequent professor at the school, Sir Harold Carpenter (1934-35). Two of these were recipients of the institution's gold medal. For the session 1956-57, another metallurgist at the Royal School of Mines, Professor C.W. Dannatt, ARSM, was to be president, and his address was to be delivered under the title 'The study of technology as a branch of education'. One of the few other presidents to make significant references to metallurgical tuition was the last to hold office in the first half of the twentieth century, W.A.C. Newman, ARSM, who entitled his address appropriately 'The role of the Institution in present-day educational developments'. Besides holding the position of chemist and assayer at the Royal Mint, for many years Mr. Newman was a part-time metallurgy teacher at the Sir John Cass Institute in the City of London, and he was personally involved in the deliberations of the joint committee on metallurgical education as representative of the Institution of Mining and Metallurgy.

As with other comparable British societies, substantial financial support for the Institution of Mining and Metallurgy came from industry. One positive way in which the institution contributed directly to metallurgical instruction was by its administration of various scholarship schemes for which industrial funds were provided. The earliest instance of such scholarships came in 1901 when a scheme was started whereby a small number of students of mining and metallurgy, individually selected by the institution, received 'postgraduate

scholarships' to travel to appropriate active industrial sites and to be maintained there during a year's work. Under this system, in the early years of the century, graduates from the Royal School of Mines, the University of Birmingham, the Armstrong College (Newcastle) of the University of Durham, King's College, London, and the Camborne School of Mines, obtained experience of conditions at mining and metallurgical sites in Western Australia and South Africa. After 1945 there came renewed and extended activity in this sector, the institution being involved in the distribution of funds from several industrial sources, most substantially the Mond Nickel Company and the Muffield Foundation, and for several successive years it was consulted in the selection of recipients for awards for study of metallurgical operations abroad. After three years' operation of the Muffield Foundation's scheme, by 1949 a total of 54 people had received grants for overseas' travel and experience.⁽⁵⁴⁾ In addition, the institution was closely associated with the establishment in London of a Muffield Research Group in Extraction Metallurgy which was to make considerable contributions to postgraduate training in research and the extension of the boundaries of knowledge. In 1948 Government asked for the institution's views on training in mineral dressing, which up to that time had been regarded as a subsidiary of courses in either mining or metallurgy; soon after 1950, the first B.Sc. degree course in the subject within the commonwealth was to be initiated at the Royal School of Mines.

By the closing years of the century 1851 - 1950 the Institution of Mining and Metallurgy was beginning to enter a new phase in which greater prominence was to be given to metallurgy than had been the case in the 1920s and 1930s, when few papers came forward. To coincide with the fourth empire mining and metallurgical congress, the institution organised a two-day meeting in 1949 on 'The refining of non-ferrous metals',⁽⁵⁵⁾ and for the first time made funds available for a distinguished lecture on an appropriate metallurgical topic. This was delivered by Dr. C.H. Desch, FRS, a former professor of

(54) NEWMAN, W.A.C., 'Presidential address'.

Trans.Instn.Min.Metall., vol.58 (1948-49), 52.

(55) SMOUT, Arthur J.G., 'Introduction'. ANON., Refining of non-ferrous metals (proceedings of a symposium held in London in July, 1949), (London: Instn.Min.Metall., 1950), 7.

metallurgy in Glasgow and Sheffield, on 'The effect of impurities on the properties of metals'. The institution's meeting on refining marked a crucial new development in its encouragement and provision of technological information relating to the mineral industry, for in subsequent years it was to organise other meetings, including a symposium in 1952 on recent developments in mineral dressing which was to prove to be the first of a series of international conferences on the subject and, in 1956, a symposium on the extractive metallurgy of some of the less-common metals. By that date too, the institution was to have sponsored publication of reports on 'The physical chemistry of copper smelting' prepared by the British Non-Ferrous Metals Research Association, and on 'The physical chemistry of melts' resulting from a symposium held by the Muffield Research Group in Extraction Metallurgy. Thus, in a number of ways, in the years after 1945 the Institution of Mining and Metallurgy roused itself from its former reluctance to take a lead in promoting metallurgical tuition and adopted a more-positive attitude and one more in keeping with the fulfilment of the responsibilities implicit in the granting in 1915 of a royal charter.

Finally, in this survey of group influences during the century 1851 - 1950, mention may be made of an instance when formal instruction was sought on the initiative of a trade body concerned with the fringes of metallurgy. This body, the Associated Foreman Smiths of Scotland, at some time in the 1920s requested the Royal Technical College in Glasgow to provide classes suitable for its members; the society guaranteed to make up 'the difference between the fees paid by the students and the fee paid to the lecturer.'⁽⁵⁶⁾ The outcome of the request is not known, but it seems unlikely that, even if one series of classes was supplied, there would be demand for tuition on a regular or extended basis.

Taken altogether, many organisations which were in existence for at least some part of the century 1851 - 1950 significantly influenced the development of metallurgical instruction, either directly or indirectly. Tuition in

(56) COMMITTEE ON TRADE AND INDUSTRY, Factors in industrial and commercial efficiency being part one of a survey of industries
(London: HMSO, 1927), 201.

metallurgy obtained benefit as the result of extended examination systems and wider availability of classes in technical subjects and because of the increased stature and academic respectability that ensued from a widened and deepened field of study. A substantial proportion of the City of London livery companies, prompted to action by public pressure in the 1870s, did much to encourage technical-instruction classes, mainly through the joint City and Guilds of London Institute but also by monetary benefactions from individual companies. The City and Guilds' Institute supported the cause of technical education in general, while certain livery companies supplied help specifically for metallurgy, as for instance in equipping laboratories at the Sir John Cass Institute in London and endowing a professorship in the University of Cambridge.

The two oldest nineteenth-century professional engineering societies, the Institutions of Civil and Mechanical Engineers, included among their membership some metallurgists, and occasionally considered metallurgical topics at their meetings. Even in the nineteenth century the Institution of Civil Engineers showed concern for vocational education and the joint committee on engineering training which was convened on its initiative soon after 1901 included representation from the Iron and Steel Institute. The report of this committee, published in 1906, recognised that one of the greatest barriers that prevented individuals from receiving reasonable amounts of training was the uncooperative attitude of many employers. The Institution of Mechanical Engineers, inspired by a few individual members, from 1890 actively promoted research into features of alloys. These investigations provided one of the first British instances of organised group metallurgical work and they influenced the decision to include metallurgy as a major sector of the National Physical Laboratory which started at the beginning of the new century. Besides the national engineering societies several regional bodies, such as the South Wales Institute of Engineers and the Cleveland Institution of Engineers, devoted parts of their meetings and publications to metallurgical topics and lent support to the development of local technical classes.

It was not only engineering societies which had relevance for metallurgy, for chemical groups, too, shared common ground. After the Institute of Chemistry was formed in London in 1877 to protect the interests and standing of chemists, a substantial number of practising metallurgists became members,

a situation that was to continue until after 1950. By 1903 two chemical learned societies with metallurgical leanings had come into existence, the Society of Chemical Industry and the Faraday Society. The latter, in particular, aided the subject of metallurgy, including its theoretical principles, by organising several discussion meetings which proved to be seminal. The engineering and chemical societies' contributions to metallurgical education resulted chiefly from the broadening of knowledge, supplemented by some encouragement for research.

With engineering and chemistry, metallurgy's third near neighbour was mining, and in 1892 there was founded a qualifying body, the Institution of Mining and Metallurgy, which sought to establish professional standards in certain portions of the fields explicit in its title. Its main concern was with mining, however, and its interest in metallurgy was limited to the production of non-ferrous metals from their ores. The institution was a convenience for London companies financing overseas metal-producing properties but, despite the inclusion of 'metallurgy' in its title, with its restricted outlook it repeatedly failed to represent the interests of most British metallurgists. Nonetheless, the Institution of Mining and Metallurgy was entrusted with the administration of schemes to encourage undergraduate and postgraduate training. In the present context a pertinent act of the institution was its organisation of the first 'Empire mining and metallurgical congress' held in London in 1924; this led to the discussion and publication of a survey of the advanced metallurgical instruction then available in the country, the first occasion on which such a comprehensive review had appeared. Professor H.C.H. Carpenter of the Royal School of Mines, who compiled the survey, took the opportunity to make the point that, in his view, there were plenty of university departments of metallurgy in existence: by implication, he thought there were more than enough to meet the low numbers of students coming forward and the small demand for the product. As several of these academic departments possessed resources which were extremely limited in the 1930s and the first half of the 1940s, the long-term interests of metallurgical education might well have been better served by a smaller number of centres, each working with adequate equipment in a beneficent environment, and directed by inspired leadership.

On the wider front, a distinctly-helpful influence was exercised by the Society of Arts and the British Association for the Advancement of Science, especially in the earlier part of the period 1851 - 1950. Both bodies included occasional metallurgical topics in their programmes, and the Society of Arts in the 1870s was responsible for initiating technological examinations which included metallurgy. By comparison, the Royal Society of London was not conspicuously active in encouraging the subject, although from 1932 to 1955 one of its Warren Research Fellowships was awarded to Dr. William Hume-Rothery, a notable worker in metallurgy in the University of Oxford.

Chapter 9

PROFESSIONAL SOCIETIES AND RESEARCH ASSOCIATIONS

The Role of Organised Groups Primarily Concerned with Metallurgy

Although metallurgical instruction in Britain has been helped considerably as the result of exertions and benefactions made by bodies such as the Institutions of Civil and Mechanical Engineers, the Institution of Mining and Metallurgy, and the London Guilds, not surprisingly it has also been advanced by a number of organisations concerned primarily with metallurgy. The one with the longest national record is the Iron and Steel Institute, in existence for eighty years of the century 1851 - 1950. For the last forty years of the period, the Iron and Steel Institute came to be rivalled in its influence by the Institute of Metals, while for the five years 1946 - 1950 another body, the Institution of Metallurgists, became significant. Two other specialist national groups which contributed were the Institute of British Foundrymen and the Institute of Welding. On a more restricted geographical scale, several local groups played their parts, notably the Birmingham Metallurgical Society, founded in 1903. Besides these 'learned societies', after 1920 a number of industrial research associations helped promote metallurgical knowledge and jobs. Altogether, in terms of the number of organisations present in the field, metallurgy was not without friends, so that appropriate instruction should have been championed; however, until the 1940s, most of the bodies were not prepared to adopt active and aggressive attitudes towards the provision of instructional facilities.

The earliest groups for the benefit of metallurgy were formed in the late 1860s. In the provinces, although the South Wales Institute of Engineers

which started in 1857 and the Cleveland Institution of Engineers founded in 1864 were not primarily devoted to metallurgical pursuits, the South Staffordshire Mill and Forge Managers' Association of 1866 was: albeit to promote harmony and business in the district's iron trade. This body, which was later to become the Staffordshire Iron and Steel Institute, did recognise the important need among ironworks' managers for greater metallurgical, mechanical, and scientific knowledge; in fact, the president in the institute's centenary year hazarded the opinion that it was the educational side which had persuaded the various proprietors 'that the objectives of the Association were ... something which they should support'. In 1887, the institute was able to make arrangements with Mason's College in Birmingham 'for evening class studies in chemistry and metallurgy'.⁽¹⁾

Forty years onwards, in 1927, the subject of technical training was again raised in the Staffordshire Iron and Steel Institute, F.S. Wilkinson in his presidential address taking the opportunity to urge that:⁽²⁾

'Everything possible should be done to encourage (industrial) research, especially among the younger generation to whom the country must look for the carrying on of industry in the future'.

He pointed out that the Staffordshire Institute

'recognises this claim by awarding annually a medal for a paper on some research connected with the iron and steel industry, carried out by a student in a technical school or college in the area which we cover.'

Commissioned in 1923, up to 1927 this research medal had been awarded twice, in both instances to students at the Technical College, Wednesbury.⁽³⁾

Wilkinson recommended employers to encourage the youths in their service to attend technical classes, as these would be advantageous alike to the youths themselves and the entire industry.

A second regional society devoted to the needs of the iron-and-steel

(1) LARKE, W.M., 'Evolution and development of a local technical society' (Staffordshire Iron and Steel Institute: centenary presidential address). Jrnl.Iron Steel Inst., vol.204, pt.9 (Sep.1966), 879, 880.

(2) WILKINSON, F.S., 'Presidential address'. Proc.Staffs.Iron Steel Inst., (Oct. 1927), 5-6.

(3) PLANT, C.H., 'The Staffordshire Iron and Steel Institute'. Iron Coal Trades Review 1867-1927 diamond jubilee issue, (1927), 184.

industry was begun in the Glasgow district in 1892: the West of Scotland Iron and Steel Institute had as an early president Professor Humboldt Sexton, ARSM, head of metallurgy in the Glasgow and West of Scotland Technical College, which later became the Royal Technical College. In 1909 the college appointed the institute's president to serve on the committee controlling the metallurgy department; in the following year the sum of £100 was granted from the institute's funds to provide a furnace for the department.⁽⁴⁾

The president of the West of Scotland Institute for the 1912-13 session, Walter Dixon, devoted^a considerable proportion of his address to general 'education'. He expressed his opinion, which he claimed had been formed as the result of fairly widespread enquiries, that since the Education Act of 1870,⁽⁵⁾

'the result of a forty years' development has evolved a system which is regarded as satisfactory by none and as unsatisfactory by most.

... The educationalists ... call ... for "more", while the remainder feel that there is already too much ... of the wrong kind, wrongly directed, wrongly administered'.

He proclaimed 'the unanimous opinion' that, for the working requirements of 90 to 95 per cent. of manual employees, any book learning outside the rudiments of 'the three Rs' was unnecessary while, among the remaining 5 to 10 per cent., most would attain to the leading positions in which they found themselves 'if three-quarters of the existing aids to learning were abolished'. Moreover, without the 'benefit' of education, the 90 to 95 per cent. of workmen would do their work better, with less 'unreasonable restlessness, and ... discontent'.⁽⁶⁾

Dixon's views, however, were not entirely destructive: he believed that educational methods should be, and ultimately would be, altered to make them valuable for equipping the workmen for their hours of recreation. In addition, and specifically referring to technical education, within the West of Scotland Institute he was anxious to promote meetings dealing with 'subjects which would be of immense benefit to the younger branch of the iron and steel workers,

(4) MacCALLUM, D.A., 'The West of Scotland Iron and Steel Institute'.
Iron Coal Trades Review 1867-1927 diamond jubilee issue,
(1927), 182.

(5) DIXON, Walter, 'Presidential address'. Jrnl.W.Scotland Iron Steel Inst.,
vol.20 (1912-13), 19.

(6) DIXON, Walter, op.cit., 13.

from whom the leaders of the future are most likely to be recruited'.⁽⁷⁾ Indeed, one such meeting was held at Coatbridge on a Saturday in January 1913, with the intention of attracting the attention of ironworkers in the district. Professor Thomas Turner, ARSM, of Birmingham University, lectured on 'The reactions of the puddling process'. The event was regarded as 'a decided success', with between 200 and 300 present.⁽⁸⁾ The question of general education was again alluded to by Walter Dixon the following year. At much the same time, in 1914, a medal with £10 book prize was founded, for presentation to the authors of papers either on original research, or on the study of problems related to the iron-and-steel industry. However, despite this gesture of encouragement, it was 1926 before the first medal was actually awarded. In 1915 the institute prepared, and later published, a catalogue of all books relating to the iron-and-steel industry which were obtainable in libraries round about Glasgow.⁽⁹⁾

The year after the foundation of the Staffordshire group, 1867, brought considerable discomfort to those, admittedly only a small minority of the populace, who attended the Paris International Exhibition: it seemed that Britain's industrial prominence was being seriously jeopardised, or even overtaken, by the technological advances made by other countries. This alarm on the one hand prompted Lord Glanville to write a letter to The Times, and on the other led both Bernhard Samuelson and Lyon Playfair to action. It also catalysed moves made in 1868 to form a national body to promote the technological interests of British iron-and-steel industry. In 1869, this emerged as the Iron and Steel Institute, a group which was to have a useful life for 104 years before merger at the beginning of 1974 as a constituent of the new Metals Society.

The Iron and Steel Institute is said to have taken root from a paper read to a gathering of north-country ironmakers at Newcastle-upon-Tyne by John Jones of Middlesbrough, secretary of the North of England Iron Trade. Appropriately, the paper was entitled 'The position of the iron trade in

(7) DIXON, Walter, op.cit., 16, 22.

(8) WEST SCOTLAND IRON STEEL INSTITUTE, 'Annual report of council for session 1912-13'. Jrnl.W.Scotland Iron Steel Inst., vol.20 (1912-13), 215.

(9) MacCALLUM, D.A., loc.cit.

relation to technical education', and in it Jones proposed the formation of a society 'to consist of individual members of the iron trade and of those intimately associated with it' to achieve for the benefit of the British trade 'the more general diffusion of technical information'.⁽¹⁰⁾ In the title of Jones's paper the call for increased technical education was clear enough. In a second paper, presented in Leeds in 1876 shortly before his premature death, John Jones propounded the view that, instead of being concentrated in South Kensington, the income from the proceeds of the Great Exhibition of 1851 should have been distributed to help establish facilities for technical education 'in the principal manufacturing and industrial districts'. A contributor to the accompanying discussion took the opportunity to draw attention to the £100 000 a year which could be derived from patent-office fees, and which in his view should have been applied by Government for technical education.⁽¹¹⁾

The new Iron and Steel Institute was formally inaugurated in London in 1869. Its founders, mostly men commercially engaged in the iron trade, had to face 'widespread unwillingness to submit ideas to open discussion ... supplemented by excessive regard to time-honoured techniques too greatly dependent upon tradition'.⁽¹²⁾ From the outset, far from being regional in character, the institute tried to be international rather than national, attracting members from abroad and making visits to foreign countries. In accordance with its broad outlook, some meetings were held outside London: these included Middlesbrough in 1879, 1908 and 1937, Glasgow in 1901, Sheffield in 1905, Leeds in 1912, and Cardiff in 1920. Further afield, meetings were arranged at Liège in 1873, in Paris in 1878 and 1921, Sweden in 1926, and the USA in 1890 and 1904. In occasional later years, overseas members were elected to serve as president, the first of non-British nationality being Andrew Carnegie.

(10) LLOYD, G.C., 'The Iron and Steel Institute' (under 'Associations and institutions connected with the iron and steel industry').
Iron Coal Trades Review 1867-1927 diamond jubilee issue, (1927),
 176.

(11) JONES, Jno., 'Technical education in connection with the iron trade'.
Jrnl. Iron Steel Inst., (1876), 342-346; discussion 346-354.

(12) TRIPP, B.R., 'The Iron and Steel Institute, 1869-1969: an historical sketch'. Jrnl. Iron Steel Inst., vol. 207 (Apr. 1969), 422, 423.

The first president of the Iron and Steel Institute, 1869 - 1871, was William Cavendish, seventh Duke of Devonshire, the chairman of the Barrow Hematite Steel Company. During his term of office he was appointed chairman of the Royal Commission of inquiry into scientific instruction, the 'Devonshire Commission'. In his address to the inaugural meeting of the institute in London in June 1869, the Duke⁽¹³⁾

'compared the position of the iron and steel industry with that in civil, mechanical, and mining engineering, and in agriculture, observing that "it must be a matter of some surprise that an institution of this kind has not been long ago called into existence".'

He also drew attention to the unfavourable contrast between British progress in the diffusion of metallurgical knowledge and that in Belgium, France and Prussia.

The Duke of Devonshire was succeeded as president by Henry Bessemer, who in turn was followed by Isaac Lowthian Bell, 1873 - 1875, whom some have described as 'the chief founder of the institute',⁽¹⁴⁾ and who was closely associated with John Jones in the launching of the project at the meeting of the North of England Iron Manufacturers' Association. A subsequent president was Bernhard Samuelson, FRS, while during the years to 1950 several men connected with the teaching of metallurgy held office. These included: John Percy, MD, FRS, (1885-1887), who established his immortality by his thirty-year occupancy of the chair of metallurgy at the Royal School of Mines following its inception in 1851, Professor Sir William Roberts-Austen, ARSM, FRS, (1899-1901), Percy's successor at the school, and Sir Harold Carpenter, FRS, (1935-37), also professor of metallurgy there. During 1946 - 1948 the president was Dr. C.H. Desch, a past professor of metallurgy in the Universities of Glasgow and Sheffield.

Printed papers presented for discussion at meetings and by correspondence formed an important part of the institute's activities. These were published periodically under the title Journal of the Iron and Steel Institute, about 1650 papers having appeared by 1927. As a large proportion of them dealt

(13) TRIPP, B.H., op.cit., 424.

(14) LLOYD, G.C., op.cit., 177.

with technical developments or improvements to existing practice, they undoubtedly contributed significantly to the extension of knowledge in the metallurgical field. Wide dissemination of the publications can only have stimulated new ideas. All questions connected with wages and trade regulations were specifically excluded by the objects of the institute.

As early as 1871 G.J. Snelus, ARSM, a metallurgist employed at the Dowlais Works, proposed that the Iron and Steel Institute should set up a laboratory for research to hasten developments in the study of iron-and-steel chemistry, but nothing resulted from this request.⁽¹⁵⁾ At almost the same date, the institute formed special committees to investigate two aspects of the industry on which information was badly needed: British iron-ore resources, and mechanisation of the iron-puddling process widely used in the conversion of molten blast-furnace metal to wrought iron. Following these early forays into industrial research, the institute dropped this means of helping industry, and it was only taken up again 40 years later in the Great War of 1914 - 1918. Despite this absence of initiative on the institute's part, encouragement both for research related to the iron-and-steel industry and for the presentation of appropriate papers has come from endowments put into its hands. These funds periodically provided medals and other awards. The earliest, and most prestigious, the Bessemer Gold Medal, was instituted with funds given by Henry Bessemer in 1873 at the end of his term as president, to encourage interest 'in the advancement of science and technology of iron and steel metallurgy'.⁽¹⁶⁾ Nearly thirty years later, in 1901, the Iron and Steel Institute was made executor of a scheme to promote research work in the metallurgy of iron and steel funded by Andrew Carnegie during his term as president, 1903 - 1905. He provided the sum of \$100 000, equivalent at the time to £20 000, and individual scholarships were worth £100 a year to the recipients. From these Carnegie Scholarships and, after about 1920, through the research committees in which the Iron and Steel Institute played a large part, money was made available

(15) MATHER, Richard, 'Presidential address. The Iron and Steel Institute and the industry'. Jrnl.Iron Steel Inst., vol. 168, pt.2 (June 1951), 122; quoting SNEBUS, G.J., 'Condition of carbon and silicon in iron', Jrnl.Iron Steel Inst., (1871), vol.1, 28-46.

(16) LLOYD, G.C., op.cit., 178.

to support research workers and projects. The 'special fund' of £10 000 created by gifts from industry, among which Dorman, Long & Co Ltd headed the subscription list with £1200, must have been of substantial help to the struggling university departments of metallurgy. In 1927 for instance, all the fund's available income was granted to aid research work carried out at Sheffield and Glasgow Universities for the Committee of Heterogeneity of Steel Ingots.⁽¹⁷⁾

In 1917 the Iron and Steel Institute set up five research committees to promote greater efficiency throughout the range of processes used by the industry. Dr. J.E. Stead of Middlesbrough was among the leaders in these early moves to develop effective research panels. With the ending of the Great War, however, four of the five committees were disbanded, leaving in an active state only that on 'metallography, chemistry, and physics': the one of the group concerned with principles rather than processes. This research committee was disbanded in 1929, the same year in which there came into being, though not wholly within the Iron and Steel Institute, and as the result of considerable Governmental prodding by DSIR, the Iron and Steel Industrial Research Council. On this, the Iron and Steel Institute had representation.

Late in the 1930s the Iron and Steel Institute was host to a discussion on the metallurgy and physical chemistry of steelmaking, prompted by a paper on 'The application of physical chemistry...' submitted by Dr. A. McCance, ARSM, of Glasgow.⁽¹⁸⁾ This event indicated how far underlying scientific principles were coming to be thought significant for industrial processes.

Regarding technical education, before 1900 four presidents of the institute remarked on 'the continuing contrast between the rigour and thoroughness of the Germans' and the situation prevailing in Britain. These presidents were: Bernhard Samuelson (1883-85), Sir James Kitson (1889-91), Sir Frederick Abel, FRS (1891-93) the War Office Chemist, and Sir David Dale (1895-97). It has been claimed that the advocacy of these men 'added impetus

(17) LLOYD, G.C., op.cit., 178.

(18) McCANCE, A., 'The application of physical chemistry to steelmaking'. Iron Steel Inst.spec.rpt.22, (Iron Steel Inst., 1938), 331-371. Discussion on metallurgy and physical chemistry of steelmaking, op.cit., 505-543.

to the movements towards an ... improved system of technical education for the UK as a whole'.⁽¹⁹⁾ However, for all its encouragement of industrial advance, in the years before 1940 the institute was not keen to become involved in actual, real schemes for training, or with the professional status of metallurgists. This avoidance of awkward responsibility was clearly exemplified shortly before 1930 when, in common with two other national groups, the Iron and Steel Institute was asked by the Board of Education to co-operate in establishing a national-certificate scheme for metallurgy on similar lines to those then recently set up for mechanical and electrical engineering and chemistry. The effort came to nothing then, though it is true that the numbers involved in metallurgy were markedly lower, both in terms of students studying the subject and members of the respective institutes. It was not until another fifteen years had passed that it became possible for agreement to be reached on the introduction of national certificates in metallurgy. The two other bodies involved with the Iron and Steel Institute were the Institution of Mining and Metallurgy and the Institute of Metals. All three had been granted royal charters, presumably indicating that the State viewed their activities as beneficial to the national interest. By 1938 some change of attitude or circumstances was evident, for in that year, having previously resisted proposals for close association, the Institute of Metals and the Iron and Steel Institute agreed to collaborate to the extent of leasing No. 4 Grosvenor Gardens, S.W.1., (formerly the American Embassy) as a joint headquarters building, including a library.⁽²⁰⁾

The Institute of Metals was then thirty years old, having come into existence in the opening decade of the twentieth century, when some of those working with non-ferrous metals felt themselves to be unrepresented by any group and considered advantages might be derived from an association relevant to their interests. As a result, in 1908, there was brought into being the Institute of Metals, an organisation intended by its founders to be a technical society parallel with the Iron and Steel Institute, thereby providing a means for promoting scientific and practical advances in the manufacture, working,

(19) TRIPP, B.H., op.cit., 426-27.

(20) INSTITUTE OF METALS, 'Co-operation with the Iron and Steel Institute'. Jrnl.Inst.Metals, vol.62 (1938), no.1, 31-32.

use, and knowledge of non-ferrous metals and alloys. All questions connected with wages, management of works, and trades' regulations, were excluded.⁽²¹⁾

The leaders of the new society recognised the desirability of achieving a reasonable balance between members of three kinds: those who were manufacturers or businessmen, those who were engineers or other users, and those who were 'professionals' such as researchers and teachers.⁽²²⁾ Support came from a number of influential people involved with metals, and notably from certain members of the Institution of Mechanical Engineers, whose initiative was largely responsible for the new enterprise.⁽²³⁾ The first president of the Institute of Metals was a former Admiralty director of naval construction (1885-1902), Sir William White, who had been president of both the Institutions of Civil and Mechanical Engineers. Another of the active leaders was Dr. H.C.H. Carpenter, who had been appointed to the new chair of metallurgy and metallography in Manchester two years before; from 1918 to 1920 he served as president of the Institute of Metals.

Professor Carpenter's 'Presidential Address' in 1918 was largely devoted to an exposition of his views on the training desirable for men 'destined to occupy technical positions in works'. His remarks were clearly concerned with the privileged few who undertook extended periods of full-time study at a technical school or university. After outlining 'the broad principles of metallurgical training' which he considered should be given in educational institutions, he observed that any such instruction could form only a part of the overall training required, the second, and no less essential, part being obtained inside the industry. In this respect the colleges' three-months' summer vacations afforded a convenient opportunity for students to obtain initial experience of works, which Professor Carpenter considered should be substantially augmented by the first one or two years following graduation. Professor Carpenter pointed out that fresh graduates, 'though they have all

(21) SELIGMAN, Richard, 'The Institute of Metals. Its origin and objects'. Chem.Edn., vol.7 (1930), 2088-89; quoting the 'earliest rules of the society'.

(22) HUTTON, R.S., 'The Institute of Metals: some recollections and reflections'. Jrnl.Inst.Metals, vol.86 (1957-58), 465. Golden Jubilee Lecture to Inst. Metals, London, Apr.1958.

(23) GUETERBOCK, P.G.J., 'Presidential address'. Jrnl.Inst.Metals, vol.72 (1946), 142.

had the same training, are men each with his special character and mental endowment'. It was the function of industry, he said, to discover the special aptitudes of each person, so that at the end of the training period, he might be 'entrusted with work which will make the best of him'. He urged potential employers to give new graduates time to find their feet, to provide them with adequate opportunities to obtain such information as they might want, and to pay them 'at any rate a living wage' during the process. (24)

Professor Carpenter suggested that by the end of their industrial training graduates would be likely to fall into one of three categories: those who, by the exercise of their sympathy and insight in addition to technical knowledge, could usefully contribute to the running of works; others who, in spite of their long training, lacked confidence or independence of mind, but who would work well and faithfully under direction, doing useful work which brilliant men would find irksome; and thirdly and rarely, the originators, imbued with the desire to innovate and improve upon existing practices, who could be employed most profitably for that purpose.

Twenty years later, when in 1938 the presidential address of the institute was once more delivered by an academic metallurgist, Dr. C.H. Desch, FRS, who had foresaken his professorship at Sheffield to become head of the metallurgy section at the National Physical Laboratory, Professor Carpenter's theme concerning the training of metallurgists was touched on, and extended. Desch suggested that 'for the research worker of the future, metallurgy should be essentially a post-graduate subject, to be studied after a thorough training in physics and chemistry.' He regarded such training as distinct from 'the more technical courses in metallurgy which are usually given, which aim at training men for the control of works operations.' (25)

Among its first six presidents the Institute of Metals had no fewer than three metallurgy teachers: besides Carpenter, these included Professor William Gowland, ARSM, FRS, of the Royal School of Mines (1912-13), and Professor A.K. Huntington, ARSM, of King's College London (1913-14). A little later,

(24) CARPENTER, H.C.E., 'Presidential address'. Jrnl.Inst.Metals, vol.19 (1918), 52.

(25) DESCH, C.H., 'A chemist's view of metallurgy. Presidential address'. Jrnl.Inst.Metals, vol.62 (1938), no.1, 47.

in the mid 1920s, a fourth academic metallurgist to become president was Professor Thomas Turner, ARSM, of the University of Birmingham. Both Gowland and Huntington had previously served as presidents of the Institution of Mining and Metallurgy.

The original aims of the Institute of Metals said nothing specifically about education or training, although such activities might be taken as implicit in the holding of meetings and publication of a periodical journal 'to advance the knowledge of metals and alloys'. In fact, in a number of ways, in the 40-year period before 1950, the institute made significant contributions to metallurgical instruction. Primarily, and most consistently, this was achieved by holding regular meetings for the exposition of theories and the discussion of both principles and practice, coupled with publication of the Journal; this contained not only printed papers but also abstracts covering a wide range of relevant metallurgical literature. One of the first metallurgical papers to be prepared by a woman was published by the Institute of Metals in 1918 as the result of war-time work at the National Physical Laboratory.

Meetings were held in British provincial towns as well as in London, and some took place abroad, notably at Ghent in 1913, Liège 1926, Dusseldorf 1929, Zurich 1931, and Paris 1936. A joint meeting with the Iron and Steel Institute, planned for the USA in 1938, was abandoned because of the unfavourable international situation. As early as 1910 a 'local section' of the institute was set up in Birmingham, and this worked closely with other societies in its area. By 1920 similar local sections had been formed in Sheffield and Glasgow, the three provincial branches having a combined membership of 300. Among the six meetings held by the Sheffield section in 1919 was one at which the subject of 'The relation of the university to local industry' was considered under the leadership of Mr. W.R. Barclay. The chairman of the new Glasgow section was Professor C.H. Desch, professor of metallurgy in the University of Glasgow until 1920, when he moved to the corresponding position in Sheffield. In Manchester, despite the early close association with the creation of the Institute of Metals, a separate metallurgical society was formed in 1919 rather than a local section of the institute. It resulted from the initiative

of Mr. E.L. Rhead, head of the metallurgical department of the Manchester Municipal College of Technology, and it had the sensible features of embracing ferrous as well as non-ferrous metallurgy and inviting membership from all those interested in metallurgy, women as well as men.

Later, local sections came into being in London, Swansea, Newcastle-upon-Tyne and, more recently, Oxford. In the later 1930s and during the 1940s some of these local sections were to provide important platforms for the promotion of views concerning metallurgical tuition, and they influenced the development of technical instruction in their localities. Where no local section existed, the Institute of Metals might be asked to supply representatives to committees involved with developments: for instance, in Middlesbrough in the 1930s, two nominees of the institute served on the Foundry Advisory Committee of Constantine Technical College.⁽²⁶⁾ By that time, the Institute of Metals and the Iron and Steel Institute were both fostering regional societies by schemes of association and financial support.

In 1936 the Institute of Metals undertook publication of a monograph which extended the range of knowledge concerning 'The structure of metals and alloys'. The work was prepared by Dr. W. Hume-Rothery of Oxford University, who had then been engaged in investigation for some ten years: it was to become a classic and 'bestseller' for a generation of metallurgy students.⁽²⁷⁾ Under the presidency of W.R. Barclay, in 1936 - 1937 the institute launched an appeal to create an endowment fund to extend its work, about £14 000 being raised by gifts from industry.⁽²⁸⁾ At the same time, the International Nickel Company Ltd provided a platinum medal 'to be awarded annually for distinguished work in any branch of non-ferrous metallurgy'.⁽²⁹⁾

In similar pattern to the fostering of metallurgical research by the Alloys Research Committee of the Institution of Mechanical Engineers and by the Carnegie Research Committee associated with the Iron and Steel Institute,

(26) INSTITUTE OF METALS, 'Report of council for year 1937'. Jrnl.Inst. Metals, vol.62 (1938), no.1, 19.

(27) HUME-ROTHERY, W., The structure of metals and alloys. (London: Inst. of Metals, 1936). Institute of Metals Monograph no.1.

(28) ANON., 'The Institute of Metals. Annual general meeting'. The Metal Industry, vol.50 (12 Mar. 1937), 532.

(29) The Metal Industry, vol.50, no.11 (12 Mar. 1937), 343.

at the annual meeting of the Institute of Metals in March 1910 it was decided to establish a Corrosion Research Committee. At the time, corrosion of brass condenser tubes by saltwater was a serious problem to steam users; the institute appealed for subscriptions, and obtained the part-time services of an investigator; the University of Liverpool gave laboratory accommodation and granted £50 a year towards costs. In 1916, through the Advisory Council for Scientific and Industrial Research, a substantial Treasury grant was obtained, and the scale of research work was stepped up, with three full-time staff using a laboratory at the Royal School of Mines combined with an experimental plant in Brighton. Altogether, the work resulted in eight reports submitted to the institute and, during the 1920s, the emergence of useful practical applications.

During the 1920s and the first half of the 1930s, little to do with metallurgical instruction was published in Britain, the single major oasis being Professor Carpenter's presentation of a composite paper on 'Metallurgical education of university rank in Great Britain' to the first Empire Congress held at Wembley in 1924. The organisation of the congress was handled by the Institution of Mining and Metallurgy rather than by the primarily-metallurgical bodies. However, the presidential address to the Birmingham Metallurgical Society in the following year, by L. Aitchison, later to become professor of industrial metallurgy in the University of Birmingham, was entitled 'On metallurgical training and the society'.

Following these isolated publications in the mid 1920s, it was a meeting in 1937 of the London local section of the Institute of Metals which provided the setting for an address on 'The training and employment of metallurgists'; this was given on 11 November as a Special Autumn Lecture by Dr. R.S. Hutton, at that time Goldsmiths' Professor of Metallurgy in the University of Cambridge.⁽³⁰⁾ By opening up the subject and stimulating discussion, it was to have wide repercussions. A few months later, a morning discussion based upon the paper was arranged by the Institute of Metals, attracting many in influential positions. Professor Hutton stated that his paper 'raised the question of whether we were training our future metallurgists aright, and

(30) HUTTON, R.S., 'The training and employment of metallurgists'.
Monthly Jrnal.Inst.Metals, vol.4, pt.12 (1937), 629-640.

whether we had planned an adequate supply'. He pleaded for the need to increase the output of metallurgical graduates, and observed that the task was to design an undergraduate training course that would be suitable for a wide range of students, 'some of whom might pass directly at the end ... into industrial occupations', while others went forward into research. He hoped⁽³¹⁾

'the discussion would help to bring the British industrial employer into touch with the importance, for the maintenance and progress of our industries, that we should have an adequate supply of man-power to draw upon for the higher posts in industry.'

Those who joined in the discussion included professors of metallurgy from the Universities of Sheffield, Liverpool and Manchester and from the Royal School of Mines, as well as other academics from Oxford (Dr. W. Hume-Rothery), Aachen (Dr. Max Hermann Haas), and the Sir John Cass Technical Institute in London. The moderate middle view of the industrial-research department was advanced by Dr. W.H. Hatfield of the Brown-Firth Research Laboratory in Sheffield, while the extreme view of the industrialist was strongly put by Mr. A.J.C. Smout, of Imperial Chemical Industries Ltd. (Metals Division). According to Arthur Smout,⁽³²⁾

'This discussion is ... very much overdue. ... it cannot be other than an indictment of the council (of the Institute of Metals) ... that this is the first occasion in our thirty years' existence when we have publicly ventilated this very important subject.'

However, as was quickly pointed out in the columns of a weekly trade paper, both by editorial leader and published correspondence, the discussions which had been stimulated by Professor Hutton lacked one important dimension because 'economic questions' were barred by the Institute of Metals' articles of association.⁽³³⁾ The poor wages and lowly status accorded to most

(31) ANON., 'The training and employment of metallurgists'.
Aluminium and Non-Ferrous Rev., vol.3, pt.5 (Mar.1938), 189.

(32) ANON., op.cit., 190.

(33) ANON., 'Industry and the metallurgist. The present position'.
The Metal Industry, vol.52, no.11 (18 Mar. 1938), 305-306;
RECORDER, 'Correspondence and discussion. Training and employment
of metallurgists'. op.cit., 321-322.

industrial metallurgists reflected their employers' estimation of their potentialities. It was proposed that young qualified metallurgists should be given better opportunities to prove their real industrial worth.

In airing the topic of metallurgical training, the example set in London by the Institute of Metals was followed some months later by an open discussion held in Birmingham in November 1938, organised jointly by the Midland metallurgical societies. No startling new views or proposals reached the published account of this meeting. In opening it, a speaker representing industry (Mr. W.F. Brazener) reminded his hearers that 'metallurgists were developed mainly in two different ways'. In one group were those who, after achieving something like matriculation standard at school, started in industrial laboratories and worked their way up to the status of metallurgists; the other group consisted of those who took a university course and then entered industry when, after relatively short experience of works' routine, they could 'undertake with intelligence any of the usual tasks that fell to the lot of the metallurgist in a works.' The same speaker considered that one of the best metallurgical training grounds was investigation of complaints and failures because, during this work, 'the fundamental characteristics of metals and alloys become deeply embedded in the mind'. He suggested there were two predominant factors which decided whether training was successful: the determination of the individual and the attitude of the employer.⁽³⁴⁾

Another speaker made the useful points that greater attention should be paid to the study of foreign languages, and that graduates from a university course should be adequately equipped to continue their own training. During the discussion, the academic viewpoint was presented by Professor D. Hanson of the University of Birmingham.

In February 1940 the subject of 'Metallurgical training in Great Britain' was again raised at a meeting of the London local section of the Institute of Metals. On this occasion a comprehensive review of formal instruction for various grades of work was given by Dr. S.W. Smith, ARSM, CBE (formerly of the Royal Mint). In its written form, at any rate, it covered the

(34) ANCH., 'The training of the metallurgist'.
The Metal Industry, vol.55 (9 Dec. 1938), 562-564.

examination facilities provided by the City and Guilds of London Institute as well as the courses at more-advanced levels offered by university departments, and it also touched on postgraduate work.⁽³⁵⁾

It is clear that, in considerable contrast with the situation existing previously, during the last few years of the 1931-40 decade the matter of metallurgical training was attracting attention and receiving open discussion. By this time the situation had changed markedly in at least two respects: there was need for metallurgists, and it had become generally fashionable to talk of 'training'. The discussions of 1938 had demonstrated that the matter was ripe for debate and, presumably, for some kind of action.

The advent of the war in September 1939 might be expected to put a stop to the further development of proposals, discussions, and ideas for improving metallurgical training but, if this was the case, it was so for only a surprisingly-short time. Moreover, the war-time demands for technically-proficient men and women underlined the need to improve the supply of trained metallurgists. Even while the war was still on, the next publicised moves were made; around 1942 the Advisory Council to the Department of Scientific and Industrial Research (DSIR) set up a committee 'to examine the supply and training of metallurgists'.⁽³⁶⁾ This was apparently part of a wider strategy involving committees and appraisals on a broad front. In 1942 the British Association for the Advancement of Science produced a 'first interim' report entitled 'Post-war university education', while in the following year there was published a White Paper on Britain's 'educational re-construction', optimistically initiated by the Board of Education. The Norwood Committee's findings on 'Curriculum and examinations in secondary schools' were also produced. In this remarkable year, 1943, Professor R.S. Hutton, whose raising of the matter of metallurgical education in London in 1937 had met with such positive response, prepared for the City and Guilds of London Institute a

(35) SMITH, S.W., 'Metallurgical training in Great Britain'.
Mining Mag.(London), vol.62 (Mar.1940), 137-144.

(36) IRON AND STEEL INSTITUTE COUNCIL, 'The training of metallurgists
with special reference to the iron and steel industries'.
Jrnl.Iron Steel Inst., vol.149 (1944), pt.1, 601P.

report: 'Higher technical education. A review of post-war requirements'.

Stimulated by the DSIR's interest in metallurgical training, the council of the Iron and Steel Institute prepared a review of the subject, particularly as it related to the iron-and-steel industries; this was published in February 1944.⁽³⁷⁾ Apparently, in common with a number of bodies such as the Institute of Physics and the Institutions of Electrical and Mechanical Engineers, the Institute of Metals also prepared a report on vocational training in the middle of 1943, but this remained unpublished.⁽³⁸⁾

The Iron and Steel Institute's report evoked an editorial article in Nature which stated that 'a severe shortage of trained metallurgists is to be expected at the end of the war'. To explain this likely shortage the following reasons were advanced:⁽³⁹⁾

'The science of metallurgy is relatively new; ... the primary principles involved in the heat-treatment of carbon steels were still a subject of debate at the close of the War of 1914-18, and it is only during the period between the wars that the metallurgist, as distinct from the chemist, has won real status in industry. ... both the demand and the supply has (sic) been limited by the severe depressions to which the industry has been subjected.

Meanwhile, great progress has been made in steel-making processes, in the development of new and stronger materials, etc., and changes in technique which involve the employment of more highly trained metallurgists.

... continued technical development will be necessary if British industry is to thrive in the highly competitive markets of the post-war period, and thus a still higher proportion of trained men will be required.'

The Nature leader considered, however, that 'the importance of postgraduate education is not sufficiently emphasised in the report.'⁽⁴⁰⁾

(37) IRON AND STEEL INSTITUTE COUNCIL, op.cit., 601P-631P. The report was also published as a separate booklet (Iron and Steel Inst., Feb. 1944).

(38) IRON AND STEEL INSTITUTE COUNCIL, op.cit., 615P.

(39) ANON., 'Training of metallurgists'. Nature, vol.153, no. 3895 (25 June 1944), 753.

(40) ANON., op.cit., 754.

The review published by the Iron and Steel Institute incorporated all the significant points that had been made at the London discussion arranged by the Institute of Metals in 1938. With one exception, the recommendations were to form the foundation for future British policy. The exception was the proposal that, even allowing for the expected increase in demand, the number of centres offering undergraduate instruction in metallurgy was too large and should be cut on the grounds that there was a shortage in the supply of the highest-grade teachers and concentration of effort was desirable.⁽⁴¹⁾ Exactly twenty years before, and with greater justification, Professor Carpenter had made the same comment concerning the excessive number of centres for high-level teaching. The reiterated recommendation is particularly interesting in view of the expansion in university and equivalent departments which was to take place during the 1950s.

At the same time that in London the council of the Iron and Steel Institute was completing its deliberations on the contents of its 'training of metallurgists', in the Birmingham district the governing bodies of three metallurgical societies held discussions which were to have far-reaching effects. These talks took place between the Birmingham Metallurgical Society, the Staffordshire Iron and Steel Institute and the local section of the Institute of Metals. They led to the passing, on 30 November 1943, of the following resolution:⁽⁴²⁾

'That this meeting of combined councils considers it urgently desirable that steps should be taken to set up a professional institution, in collaboration with existing institutions or otherwise, to establish a recognised standard of competence and integrity for metallurgists.'

The desirability of creating such a professional institution had already been put forward, for example in a letter published in The Metal Industry in 1938,⁽⁴³⁾ and in the Journal of the Institute of Metals by correspondence

(41) IRON AND STEEL INSTITUTE COUNCIL, op.cit., 609P.

(42) JENKIN, J.W., 'Metallurgy as a profession'.
The Metal Industry, vol.67 (30 Nov. 1945), 363.

(43) RECORDER, 'Correspondence and discussion. Training and employment of metallurgists'. The Metal Industry, vol. 52 (18 Mar. 1938), 321-322.

which originated from Dr. Marie Gayler of the National Physical Laboratory and Mr. W.E. Ballard of the Birmingham Metallurgical Society.⁽⁴⁴⁾

The Midlands resolution was sent to the Institute of Metals, the Iron and Steel Institute, and the Institution of Mining and Metallurgy; the councils of the two former bodies adopted the proposal with keenness. As the result, after negotiations a new body, the Institution of Metallurgists, was created, its formal launching taking place in London in November 1945, following incorporation on 15 September as 'a company limited by guarantee and not having a share capital'.⁽⁴⁵⁾ Dr. J.W. Jenkin, who was one of the active promoters of this institution, in the autumn of 1945 stated that its functions, as he saw them, would be to:⁽⁴⁶⁾

'... bring within one professional body qualified metallurgists engaged in production, research, teaching, consulting work, inspection, and other metallurgical activities associated with any branch of industry.

... establish qualifications that will be the "hallmark" of competence in the science and practice of metallurgy.

... set high standards for admission as Fellows, Associates, and Licentiates.

... promote the welfare of the profession ... and co-operate with all organisations seeking to advance the study of metallurgy.

... promote better education and training ...

... not in any sense at all to act as a trade union.'

The founding president of the Institution of Metallurgists was Dr. Harold Moore, CBE, a Middlesbrough man who had for a number of years directed metallurgical research at the Royal Arsenal in Woolwich. He was succeeded as president for 1946 - 1947 by Dr. J.W. Jenkin, author of the description quoted immediately above.

(44) JENKIN, J.W., loc.cit.

(45) INSTITUTION OF METALLURGISTS, 'Report of council for the period ending 13th June 1946'. Bull.Instn.Metallurgists, no.1 (July 1946), 6.

(46) JENKIN, J.W., loc.cit.

A joint education committee was set up in 1945 between the Iron and Steel Institute, the Institute of Metals, and the Institution of Mining and Metallurgy, the last being the 'professional' or qualifying body of the three. Among the prime objects of this committee was co-operation with the Board of Education in the starting of a national certificate scheme for metallurgy. A prize fund established by the three societies enabled books to be awarded to nineteen of the successful candidates in the examinations of 1947, and to seventeen in 1948.⁽⁴⁷⁾ One of the earliest actions taken in conjunction with the new Institution of Metallurgists was the enlargement of the metallurgical education committee to include it; the Institute of British Foundrymen also became a participant. By mid 1948 the committee consisted of twenty-one members, including representatives of industry, universities, technical colleges, and the City and Guilds of London Institute.⁽⁴⁸⁾ Soon after its foundation it was stated that the committee would⁽⁴⁹⁾

'advise and co-ordinate the policy of the councils on all matters concerning metallurgical education. It will also draw attention to the requirements of industry, advise those responsible for teaching and assist ... in guiding boys in the choice of future careers.'

To further its aims the joint education committee prepared and distributed several documents, the first and the one with widest circulation being a booklet, Metallurgy a scientific career in industry, published in 1946; this sought to establish some kind of contact with schools, where the general level of knowledge or understanding of metallurgy was held to be extremely poor. Two years later a second edition was produced, and copies were sent to Local Education Authorities, technical colleges and secondary schools, over 6000 being distributed.⁽⁵⁰⁾ An attractively-presented booklet of 38 pages,

(47) JOINT COMMITTEE ON METALLURGICAL EDUCATION, 'National certificates in metallurgy' (Announcements and news). Jrnl.Iron Steel Inst., vol. 160 (Oct. 1948), 213-4.

(48) JOINT COMMITTEE ON METALLURGICAL EDUCATION, 'Report on progress ...' (Announcements and news). Jrnl.Iron Steel Inst., vol.160, pt.1 (Sep.1948), 95.

(49) JOINT COMMITTEE ON METALLURGICAL EDUCATION, 'Metallurgy in the news'. Chem. and Industry, (19 Jan.1946), 35. The statement also appeared, with minor variations, in several other publications in the early part of 1946.

(50) JOINT COMMITTEE ON METALLURGICAL EDUCATION, 'Report on progress ...' (Announcements and news). Jrnl.Iron and Steel Inst., vol.160, pt.1 (Sep.1948), 96.

Metallurgy a scientific career in industry contained considerable information put in a straightforward way. The subject's scope was surveyed under the headings 'the metallurgist's field', 'British metallurgical industries', 'research', 'education and qualifications', 'opportunities', and 'professional status'. The booklet listed universities providing degree-level courses in metallurgy, technical colleges with courses leading to national certificates, and colleges offering other courses in the subject. In the 1948 edition of the work the college lists were said to be compiled in December 1947, but a note cautioned that they might 'prove incomplete within a short time ... since the ... position is rapidly changing'. Further lists gave the names of national and local societies interested in metallurgy, a total of twenty-two local bodies being included.⁽⁵¹⁾

There followed from the committee in 1948 a six-page pamphlet, 'Recommendations on qualifications for entrance to the university schools of metallurgy'; this was stimulated, at least in part, by the 1947 report of the Secondary Schools Examination Council. Two years later the committee had produced, and was circulating, a report on 'Recommendations on university full-time degree courses in metallurgy'. Attention was then turned to the preparation of a larger work of nearly 50 pages entitled 'The education and training of metallurgists' which was to deal with the topic at all levels.⁽⁵²⁾ There is thus substantial evidence that the joint committee on metallurgical education was active in the years after 1945; certainly its publication Metallurgy a scientific career in industry may have had a favourable influence in introducing people to the subject and encouraging them to consider it as a possible means of earning a livelihood.

In contrast with the older Institute of Metals and the Iron and Steel Institute, whose membership was open to all with few restrictions, the Institution of Metallurgists set out to be a qualifying body, with membership strictly limited to those who satisfied the stringent entry requirements. The first Licentiate and Associateship examinations for admission to the Institution of Metallurgists were held in September 1947 in London, Glasgow,

(51) PAYNE, F. Lewis, Metallurgy a scientific career in industry.
(London: Joint Committee on Metallurgical Education, 1st edn. 1946; 2nd edn. 1948), 35-38.

(52) 'A.D.M.', 'The board of metallurgical studies and examinations'.
Bull.Instn.Metallurgists, vol.4, no.3 (August 1953), 16,17.

Sheffield and Swansea. 'Eleven candidates sat the Associateship papers and eight sat for Licentiate-ship, four candidates passing in each.'⁽⁵³⁾ In 1949 thirty sat for the Associateship, with 41 for the Licentiate-ship and one for the more-advanced Fellowship. The following year, 1950, the Institution's council approved the holding of examinations abroad, and it also established an education committee of its own.⁽⁵⁴⁾ By this date, some thirty industrial companies had made donations to the funds of the institution. Its Licentiate-ship (LIM) qualification soon came to be accepted as equivalent to a pass degree, with the Associateship (AIM, up to the 1970s) corresponding to an honours degree: for acceptance to the grade of Fellow, apart from other requirements, a minimum age of 35 was stipulated. The Associateship became accepted as entitling a teacher to be classed as a 'graduate' under the Burnham Further Education Report.⁽⁵⁵⁾

In the first few months after its inception, the Institution of Metallurgists began to spread a metallurgical viewpoint. Besides its participation in the joint committee on metallurgical education, it had representatives in 1946 on the joint council of professional scientists and on the parliamentary and scientific committee.⁽⁵⁶⁾

In 1947 the Institution of Metallurgists arranged a Refresher Course intended to provide those attending with an up-to-date survey of some particular aspect of metallurgical practice. As this move proved popular, further refresher courses were organised in succeeding years, most of them taking place at weekends and based on appropriate residential accommodation. For example, in 1949 the course was held in September at Ashorne Hill near Leamington Spa, with the title 'The fracture of metals'.

The first provincial meeting of the institution was held in Birmingham in March 1947, when over 150 members were present. At this meeting Sir Arthur

(53) JOHNSTON, R.D., 'Metallurgical education: a profile of the institution's educational activities since 1945'. Metallurgist Materials Technologist, vol.9 (Feb. 1977), 78.

(54) JOHNSTON, R.D., loc.cit.

(55) INSTITUTION OF METALLURGISTS, 'Recognition of the associateship of the institution in the Burnham Committee's reports'. Bull.Instn.Metallurgists, vol.2, no.5 (Mar.1950), 7.

(56) INSTITUTION OF METALLURGISTS, 'Report of council for the period ending 13th June 1946'. Bull.Instn.Metallurgists, no.1 (July 1946), 9.

Smout (he had received a knighthood in the Birthday Honours, June 1946) delivered an address on 'The place of the qualified metallurgist in industry'.⁽⁵⁷⁾ The following week another provincial meeting of the institution was held in Sheffield, 130 members attending. Although the address that was given had the same title as the one in Birmingham, the speaker was different, on this occasion being Mr. R. Mather.⁽⁵⁸⁾ These instances will show that the new institution was anxious to publicise the topic of metallurgical instruction, and that significant numbers of people were prepared to hear about it.

Later in the same year, 1947, Sir Arthur Smout spoke to another gathering on much-the-same subject: this time the Swansea local section of the Institute of Metals.⁽⁵⁹⁾ The subject of metallurgical education was given further ventilation at the end of 1948 when Professor Hugh O'Neill, newly-appointed to University College Swansea, delivered a lecture on the topic in Birmingham, acting on behalf of the Institution of Metallurgists. Professor O'Neill repeated his lecture in Manchester in March 1949.

A further venture which the institution put into effect in July 1950 was the mounting of an exhibition 'Metals in the service of mankind'. This exhibition was held at the Science Museum in South Kensington for some three months, its object being to awaken interest in metals and the techniques associated with them. Exhibits were provided by the major research and development associations and by firms working in highly-specialised metallurgical fields.⁽⁶⁰⁾

Although Dr. Jenkin had expressly declared that the Institution of Metallurgists would in no sense act as a trade union, it did seek to ensure that those hired as metallurgists were paid a reasonable level of wages, thereby encouraging enhancement of the profession's image.⁽⁶¹⁾

Outside the new institution, academic metallurgists found themselves asked to address groups on the subject of vocational instruction. Thus, in 1946 members of the London local section of the Institute of Metals heard a

(57) ANON., 'Provincial meetings. Birmingham. Address by Sir Arthur Smout'. Bull.Instn.Metallurgists, no.3 (May 1947), 14-27.

(58) ANON., 'Sheffield. Address by Mr. R. Mather. The place of the qualified metallurgist in industry'. Bull.Instn.Metallurgists, No. 3 (May 1947), 32-37.

(59) SMOUT, Sir Arthur, 'The metallurgist in industry'. The Metal Industry, vol.71 (28 Nov.1947), 439-441; (5 Dec.1947), 465-466.

(60) ANON., 'Exhibition in 1950 "Metals in the service of mankind"'. Bull.Instn.Metallurgists, vol.2, no.6 (May 1950), 14.

(61) SMITH, Dr. A.E.W., personal communication, 1981.

paper by Professor D. Hanson of the University of Birmingham on 'The university training of metallurgists'. At much the same time, another member of the metallurgy staff of Birmingham University, Dr. T. Wright, delivered an address with the identical title when he took office as chairman of the Birmingham Metallurgical Society; before the decade was out, the Professor of Metallurgy in the University of Sheffield, Dr. J.H. Andrew, had joined the ranks of those publishing articles on 'the training of a metallurgist'.

In 1946, in the first presidential address to the Institute of Metals for eight years because of the war, P.G.J. Gueterbock, CB, DSO, pleaded for the elimination of soul-destroying jobs, suggesting that, as far as his industrial activities were concerned, the metallurgist had a responsibility to bring this about. Gueterbock also observed that the Institute of Metals could look forward to 'maintaining, and where necessary instituting or reviving, great schools of ... metallurgy which will produce the trained professional men so necessary ...'.⁽⁶²⁾ He went on to comment that

'These schools must be backed by a vigorous and healthy industry which can offer a good career and way of life to the professional man and ... support ... fundamental scientific work, the sole object of which is the better understanding of metallurgical phenomena.'

That was the optimistic mood expressed after the Second World War, in 1946. It was a generation earlier, in the aftermath of the Great War, that there appeared the first of another kind of metallurgical grouping: the research associations. These bodies were persuaded into existence by the DSIR and nurtured by public funds, especially during their early years, for the purpose of stimulating and achieving research of benefit to the companies within individual British industries. One of the first of such collaborative organisations was the Cutlery Research Association of 1919, but this soon collapsed for want of support from the cutlery trade and was not to be resurrected until 1952.⁽⁶³⁾ The next metallurgical group to be established was the British Non-Ferrous Metals Research Association (BNFMRA) of 1920.

(62) GUETERBOCK, P.G.J., 'Presidential address'. Jrnl.Inst.Metals, vol.72 (1946), 147.

(63) CARTER, C.F. and WILLIAMS, B.R., Industry and technical progress. (London, etc.: OUP, 1957), 219.

This fared considerably better than the cutlers' co-operative, so that in 1946 it had an income of £46 000, sixth highest among the twenty-five grant-aided research associations; in 1979, BNFMRA's income was to be £1.2 million. In its early years the BNFMRA established its own laboratory in the University of Birmingham,⁽⁶⁴⁾ moving to fresh premises in London in 1930. Also in 1920 was created the British Refractories' Research Association, which presumably included activities with metallurgical relevance; in 1921 came the British Cast-Iron Research Association. In 1925 at Imperial College London work on the mechanism of blast-furnace reactions was financed by a group representing trade interests, the National Federation of Iron and Steel Manufacturers:⁽⁶⁵⁾ in 1934 this became the British Iron and Steel Federation (BISF). In 1929 there was formed the Iron and Steel Industrial Research Council, a committee on which the Federation was represented, as well as the Iron and Steel Institute, the DSIR, and other bodies.⁽⁶⁶⁾ In the mid 1940s this was reconstituted as the British Iron and Steel Research Association (BISRA); with its 1946 income of £95 000, this ranked fourth among the various research associations. By 1953 BISRA was to have an industrial income of £312 000 supplemented by a Government grant of £150 000, and to support a staff of nearly 400.⁽⁶⁷⁾

These Government-aided research associations produced results which extended the frontiers of knowledge. In addition, in several ways they directly furthered metallurgical training: they created demand for graduates within the various industrial establishments where their projects were pursued; and they sponsored and supported some research programmes within academic departments. True, the numbers of people affected were small, but nonetheless they formed a significant proportion of the total from British universities graduating in metallurgy. The investigations forged useful links between academics and industry, doing much to break down some of the entrenched

(64) HEATH, H. Frank and HETHERINGTON, A.L., Industrial research and development (London: Faber, 1946), 102.

(65) ANON., 'British Iron and Steel Research Association' (Announcements and news). Jrnl.Iron Steel Inst., vol.181 (Dec.1955), 353.

(66) TRIPP, B.H., op.cit., 429.

(67) JONES, W.R.D., 'Presidential address (S.W.)'. Trans.Instn.Mining Engrs., vol.113 (1953-54), 743.

prejudices about college graduates that existed in the minds of British businessmen.

Bodies with similar influences on metallurgy, although with activities not necessarily on the same scale as those of the BNFIRA and BISRA, were the British section of the International Tin Research and Development Council and the Institute of Welding. The Tin Council established laboratories at Greenford in Middlesex in the late 1930s.⁽⁶⁸⁾ The Institute of Welding, with a research council, was created in 1935 from the Institution of Welding Engineers; ten years later a Welding Research Association was formed as a distinct entity to conduct appropriate work.

The British Cast Iron Research Association fostered a direct instructional development in the 1930s by organising a foundry school to provide one-year residential courses for industrial employees who already possessed practical training. The costs of attendance were to be met by the employers, and the object was to produce 'men who were "mixtures of metallurgist, engineer and foundry technologist".'⁽⁶⁹⁾ However, despite the fact that some companies incorporated the course into their works' training schemes, the school did not long survive; it was the forerunner of the National Foundry College, sponsored by the Board of Education, which opened in 1948 in premises provided by the Wolverhampton and Staffordshire Technical College. The Institute of British Foundrymen had representation on the governing body of this college and also collaborated in the establishment of a higher national certificate in foundry technology and in the maintenance of standards of the City and Guilds' courses in foundry practice and pattern making.

By 1940 the Iron and Steel Institute similarly had representatives on the metallurgical advisory committee of the City and Guilds' Institute and a say in the running of several colleges, including specifically the Constantine College in Middlesbrough, the 'home committee' of Hong Kong University, the Imperial College of Science and Technology, Sheffield University, Liverpool University, and the School of Metalliferous Mining in Cornwall.⁽⁷⁰⁾

(68) KEATH, H. Frank and HETHERINGTON, A.L., op.cit., 106; 102-3.

(69) IRON AND STEEL INSTITUTE COUNCIL, op.cit., 627P, fn 54.

(70) IRON AND STEEL INSTITUTE, 'Report of council'.
Jrnl.Iron Steel Inst., vol.141 (1940), no.1, 42P-43P.

The British Iron and Steel Federation, in the last few years before 1950, began to devote significant funds to training, and metallurgy was among the subjects which benefited. In 1948 a new recruitment and training committee began work 'with the dual function of devising means of encouraging recruitment into the industry and of helping firms to train the recruits, once obtained.' Much of the incentive for this initiative came from the Government's Youth Employment Service, then recently established.⁽⁷¹⁾ The following year a discussion meeting was attended by 'some 100 training officers and others interested in training, representing nearly 50 companies', and area committees were set up to assist companies to launch training schemes suitable for their particular needs.⁽⁷²⁾ As part of the new policy, the BISF sponsored three-day annual conferences on 'Education and training in the steel industry' and was instrumental in producing a wide range of training aids. These included a series of booklets describing the technical features of making iron and steel under the general title of 'Lecture notes on iron and steel', wallcharts, filmstrips, and instructional films, as well as recruiting brochures giving details of careers in the industry. In addition, a textbook on iron making and steelmaking was commissioned.

There is considerable evidence to conclude that without the existence of the various metallurgical organisations the quantity of metallurgical knowledge available in 1950 would have been restricted in scope and small in scale. Moreover, the academic subject would have been arid and partly sterile without industrial influence to keep it in touch with reality; in many instances the important link with industry was formed by a well-defined organisation. In the last thirty years of the period 1851 - 1950 bodies of two kinds were significant, learned societies and industrial research organisations. Learned societies for certain aspects of metallurgy existed both nationally and in some regions. An appropriate professional society, the Institution of Metallurgists, came into being only during the last five years before 1950.

The Iron and Steel Institute founded in 1869, and the Institute of Metals created in 1908, were the national learned societies which between them

(71) BRITISH IRON AND STEEL FEDERATION, 'Recommendations for the establishment of training schemes for young workers ...' (London: the Federation, c.1949), 3-4.

(72) BRITISH IRON AND STEEL FEDERATION, op.cit., 9-10.

purported to cover most of the spectrum of metallurgical endeavour. By 1940, when the two societies had amassed a combined total of 100 presidential years, nine academic presidents had held office. In the Institute of Metals five academics held office in thirty years, and it seems likely the number was no higher simply because there were available no others thought to be of similar stature. In itself this is a measure of the relatively small extent of academic metallurgy. Both these national societies fostered metallurgical education in its wider sense by providing opportunities for meetings where technical developments and reviews of practice were described and critically discussed, and by publishing papers in permanent written form. The exclusion from the institutes' deliberations of all references to wages, trade and management was certainly understandable in view of the fact that membership was open to all and included fair proportions of successful, though academically-unqualified, industrial proprietors. Encouragement by the Iron and Steel Institute of formal metallurgical instruction and the concomitant raising of academic standards was minimal, at least for the first fifty years of its existence, although means towards these ends were put into its hands, notably by Henry Bessemer with funds for the award of an annual gold medal to mark illustrious achievement, and by Andrew Carnegie with substantial sums to give stimulus to, and support for, research. In the two decades after 1901 the rare Carnegie scholarships for postgraduate research constituted one of the few sources of help available in metallurgy.

In considerable contrast with the two learned societies was the Institution of Metallurgists which came into existence in 1945, reflecting the increased vigour and extent of national metallurgical endeavours. The new organisation was concerned with professional standards of competence and recognition, and it quickly began to give active attention to education and training, setting up a system of qualifications in metallurgy and instituting week-end refresher courses.

The national metallurgical bodies were supplemented in some areas by regional societies, two primarily concerned with iron and steel existing in South Staffordshire and, from the 1890s, in the West of Scotland. Both provided platforms on occasion for presidents to urge the desirability of better technological training and they encouraged such training by gifts of medals to individuals and apparatus to teaching departments. In Birmingham in 1903 a metallurgical society was formed which in the following years proved to be

outstanding in its activity, championing the need for instruction and urging the creation of an appropriate professional institution.

The other important prong of metallurgical group activity was supplied by the industrial research associations; these came into being in a number of fields during the last thirty years of the period 1851 - 1950 as the result of encouragement by the Department of Scientific and Industrial Research which disbursed Government funds for the purpose. Several research associations were primarily concerned with metallurgy. Although the numbers they employed directly were small, particularly before 1940, nevertheless they did give some employment opportunities to those who had received formal tuition, thereby promoting such training. By their activities the research associations also widened the industrial demands for the services of metallurgists; they helped to forge useful links between industry and teaching institutions; and they aided the survival of academic metallurgy departments. In the last few years of the period, after 1948, and arising from incentives offered by the Government's new youth-employment scheme, the British Iron and Steel Federation began to devote substantial sums to training.

Organisations, then, were used as convenient vehicles for the propagation of their views by individuals, by industrial companies, and by Government.

Despite the favourable statements uttered during presidential addresses, the two national societies, the Iron and Steel Institute and the Institute of Metals, showed marked reluctance to become the direct sponsors of instructional schemes, as evidenced by the failure of the national certificate proposals around 1930. By that date, however, the climate of opinion was already beginning to change, and by 1940 the subject of metallurgical training, and the allied one of the commercial status of the metallurgist, were receiving open debate. There is a striking contrast between the almost-complete absence of publicity given to the topic of instruction in the years up to 1937, and the extensive comment that appeared during the 1940s. The turning point can be related to several factors: the up-turn of the economy in the later 1930s; the growth of processes and materials needing technological skill; and the emergence of realisation by industrial employers that trained metallurgists, even those coming directly from university departments, might justify their hire. Until after 1950, a preponderance of the publicity was concerned with university graduates rather than with the need and means for instructing supporting staff such as technicians.

CHAPTER 10

SOME PERSONAL INFLUENCES ON METALLURGICAL INSTRUCTION

There is no doubt that a large number of individuals, by their actions, contributed to the development of metallurgical instruction in the century 1851 - 1950. Separately the impact of their contributions varied widely while collectively they were responsible for achieving much progress. At one end of the scale was Andrew Carnegie, providing sufficient funds to support three or four research workers over a period of many years. At the other end were men up and down the country prepared to devote one or two evenings a week, after their normal work, to help students who were attending evening classes in some aspect of metallurgy. The fact that these dedicated evening-class teachers receive no further mention in this chapter is not to belittle their efforts, but in general they were not innovators, and it is innovation, the opening up of new avenues, and the making possible of courses of action, which are of concern here. Moreover, it is the large-scale effect achieved by a single person which is examined.

In many cases it is difficult to distinguish between the influence of an individual and that of the organisation with which he was associated, be it government office, commercial company, or university department. However, in surveying the field there are several individuals who stand out. There may be others whose achievements would merit note but who are not included because their personal efforts are obscured by their surroundings.

The activities of the few conspicuous individuals fall into one of two categories: either they were directed towards improvement in facilities for

general technical training, or they were devoted to raising the status of metallurgists specifically. One person whose efforts made notable impact on the status of technical instruction in general, including that in metallurgy, was Dr. H.S. Hele-Shaw (b.1854-d.1941), inventor and academic. Early in his career he had the distinction of being the first professor of mechanical engineering in the University College of Liverpool from 1885 and then, between 1904 and 1906, was the first professor of civil, mechanical and electrical engineering, and at the same time principal, of the Transvaal Technical Institute and organiser of technical education in the Transvaal. From 1906, when Dr. Hele-Shaw had entered his own second half century, he pursued work as a consulting engineer in London.⁽¹⁾ In 1920 he was chairman of the education committee of the Institution of Mechanical Engineers when it was approached by Dr. A. Morley, then staff inspector of engineering at the Board of Education; as a result of those discussions there developed the national certificate scheme, the first examinations in mechanical engineering being held in 1922.⁽²⁾ Until 1937 Hele-Shaw was chairman of the joint administration committee.⁽³⁾ Corresponding arrangements for nation-wide schemes of instruction and qualification, endorsed jointly by the Board of Education and the professional body concerned, quickly followed for electrical engineering and chemistry, but there was considerable delay before a similar programme was inaugurated for metallurgy. Eventually, however, in the last five years of the hundred year period 1851 - 1950, a national certificate scheme for metallurgy materialised. Without Hele-Shaw it might not have happened in quite the same way.

Three of the six successive men in charge of metallurgy at the Royal School of Mines during the century 1851 - 1950 were particularly successful in extending the status of metallurgy and the scope of metallurgical knowledge: they were John Percy, in post from 1851 to 1880, W.C. Roberts-Austen (1880-1902)

(1) GUY, H.L. 'H.S. Hele-Shaw 1854-1941'. Obit. Notices Fellows Royal Soc. (London), 1939-41, vol.3, 792.

(2) CRADDOCK, S.R., 'The inception of the national certificate scheme'. Vocat. Aspect, vol.13, no.26 (Spring 1961), 48.

(3) GUY, H.L., op.cit., 805-806.

and H.C.H. Carpenter (1914-1940). John Percy, admitted a Doctor of Medicine in the University of Edinburgh and elected a Fellow of the Royal Society of London for his pathological researches, was appointed lecturer on metallurgy at the Royal School of Mines in 1851, the year the institution was formally established, becoming at the same time metallurgist to the Museum of Practical Geology;⁽⁴⁾ he continued to hold this joint position for nearly thirty years of the century under review. Throughout this period he was the sole regular and responsible teacher of metallurgy in Britain, and was thus able to influence without opposition a whole generation of those day-time and evening students who attended the metallurgy classes at the school. Admittedly the numbers were small, in most years probably countable on the fingers of one hand, but a significant proportion went forward to make notable impact in responsible positions, and this fact can be taken as some measure of Percy's influence: he trained others who successfully carried on the torch he had kindled.

Former students of Percy's included public analysts and industrial chemists such as William Baker of Sheffield and William Weston of the Admiralty, as well as those who took part in changing Britain from the age of iron to that of steel. Among the latter were William Hackney, Edward Riley, J.H. Westmoreland, G.J. Snelus, P.C. Gilchrist and, as an evening-class student, S.G. Thomas. In the north of England a former student, R.S. Benson, became managing director of Ashmore, Benson, Pease & Co. Ltd., engineers of Stockton, while another, Thomas Gibb, became a leader of the Tyneside copper industry. A substantial proportion of Percy's students were to make their marks as teachers of technical subjects: Leonard Brown was both a 'science teacher' and chemist to iron works, while W.H. Greenwood was for a time professor of engineering and metallurgy in the new Technical School in Sheffield in the 1880s. One man, E.F. Mondy, went to Tokyo to teach at the Imperial College of Engineering while another, Henry Louis, following several years' practical work, took up a post in Newcastle-upon-Tyne as professor of mining in the University of Durham and lecturer on metallurgy. A.K. Huntington held the professorship in metallurgy at King's College London for nearly forty

(4) ANON., 'Obituary, Dr. John Percy', Jrnl.Iron Steel Inst., (1889), no.1, 210.

years, J.J. Beringer taught assaying to a generation of students at Camborne School of Mines in Cornwall, and James Taylor for a short time held the position of demonstrator in metallurgy at Owen's College in Manchester. Three men who received instruction from Percy were to bear particularly-close relationship to him: W.C. Roberts (later Roberts-Austen) was to succeed him at the Royal School of Mines, being accorded the title 'professor'; William Gowland, a student of 1868-1870, was in turn to succeed Roberts-Austen at the school; while Hilary Bauerman in 1889 took over Percy's work at Woolwich. Bauerman, who in 1853 had the distinction of being among the first three matriculated students to graduate from the Royal School of Mines, was lecturer in metallurgy in Sheffield in 1883 and, from 1889, lecturer on metallurgy in the Royal Artillery College at Woolwich.

Percy's influence on instruction was not confined to his contacts with students at the Royal School of Mines: another position he filled for twenty-five years from its inception in 1864 was that of lecturer on metallurgy to the small but select band of artillery officers which comprised the advanced class at Woolwich. In this capacity, Percy started and maintained the practice of taking his students on works' visits, a system which was later extended, both to other subjects of the Woolwich course,⁽⁵⁾ and to metallurgical instruction at the Royal School of Mines. Percy was also examiner in metallurgy for the Science and Art Department, and thus largely responsible for the syllabus content and the standards of attainment expected. Nor was this all, for with considerable and sustained energy, Percy compiled comprehensive textbooks dealing with the major metals and with fuel: these were first issued in the early 1860s. Some at least were translated into French and German and went through several printings, forming the basis of much metallurgical teaching until the end of the nineteenth century. A further compilation of his, although in this case a singular one, was a large collection of illustrative metallurgical specimens, purchased for £500 in the year of Percy's death by the Science Museum in London.⁽⁶⁾

(5) JOCELYN, J.R.J. HOGG, O.F.G. and CADDY, J.A., Some notes on the history of the advanced class 1866 - 1939. (Woolwich: General meeting of advanced class dinner club, n.d., c.1955), 13.

(6) CACKETT, Susan, 'The Percy collection - a unique view of metallurgical evolution'. Metallurgist Materials Technologist, vol.11, no. 2 (Feb. 1979), 79-81.

Percy was fortunate to have a good private income. It is true that, in the 1860s and 1870s, he met little technological opposition to his ideas and methods while, with his dynamic personality, as well as by the combination of his official position at the Royal School of Mines and his independence of financial means and of mind, he could make a favourable impression on industrialists and others. Percy was in a social position to influence people, for he held the post of superintendent of ventilation to the Houses of Parliament, and thus had the chance to make contact with the leading politicians. During the 1850s and 1860s he appears to have been the right man in the right place. However, by the late 1870s, when he was already in his sixties, he was considerably out of sympathy with the educationalists such as T.H. Huxley, and their philosophical ideals of what was wanted for the people of the country. In view of this rift, it is interesting to note that a nephew of T.H. Huxley's, James Henry Huxley, took the metallurgy course at the Royal School of Mines; following graduation he was appointed chemist in 1872 to the Sheffield steel company, Naylor, Vickers.⁽⁷⁾

Percy's renown was as a metallurgical expert and teacher, and not as either a progressive educationalist or a politician. He lost his controversy with Huxley and the associated 'progressives', and resigned his position in the Royal School of Mines in December 1879 rather than acquiesce in the transfer of his classes and laboratory from Jermyn Street in London's West End to the newly-developing South Kensington. At this time, a good deal of Percy's available energy was spent in profitless inveighing against 'the system' and, presumably partly as a result of this, the large amount of material which he was said to have collected for the revision of his books remained unused at his death. However, one further instance of Percy's long-term encouragement of metallurgical knowledge occurred six or seven years after he had retired from the Royal School of Mines: in 1887, when he was awarded the Miller prize of the Institution of Civil Engineers, he requested this should be spent on a microscope and associated equipment for the study of metal structures,

(7) WILLEY, G.B., 'Ferrous metallurgy: 100 years' contributions by the Royal School of Mines'. Iron Steel, vol.24 (May 1951), 155.

'to be at the disposal of any member of the Institution desirous of undertaking such studies, but who might be debarred from doing so by the costly character of the apparatus'.⁽⁸⁾

Percy's immediate successor at the Royal School of Mines was W. Chandler Roberts, who soon changed his name to Roberts-Austen and proved to be a diplomat rather than a solitary dogmatist. He was a past student who for ten years had held the distinguished and singular official position of chemist to the Royal Mint. While in this post he had established a reputation as a laboratory investigator of metallurgical phenomena, and had been elected a Fellow of the Royal Society in 1875. On Percy's resignation, while retaining his post at the Mint, 'Roberts-Austen was invited by the Lord President of the Council to occupy the Chair of Metallurgy at South Kensington'.⁽⁹⁾ Although it could be argued that regular attention to Mint duties handicapped his professorial efforts, at the same time there were considerable benefits arising from the dual arrangement. Within the metallurgy department of the Royal School of Mines there was scant equipment and, at any rate in the 1880s, Roberts-Austen's only staff assistant was the instructor in assaying, Richard Smith, who had previously served as Percy's laboratory assistant. For the last twenty years of the nineteenth century Roberts-Austen pursued metallurgical research using the facilities of the Mint. Whenever he spoke at public meetings and to his students it was as a man holding a well-recognised, responsible position. Moreover, it seems likely that the salary offered to take charge of metallurgy in South Kensington was totally inadequate to attract^a/competent man unless, like Percy, he possessed another source of income.

Roberts-Austen showed that metallurgical study could be respectable, and he himself was in the forefront of developments in knowledge through technological research, being known internationally for his researches, as well as by his official position at the Royal Mint. He was active in many groups, reading papers before the Royal Society, the Society of Arts, the Royal Institution, the British Association for the Advancement of Science,

(8) ANON., Obit., op.cit., 212.

(9) SMITH, S.W., 'A centenary lecture on the life and work of Sir William Chandler Roberts-Austen'. Delivered at the Instn.Mech. Engrs., March 1943, offprint, 15.

and the Iron and Steel Institute. In these ways he contributed largely to the spread of understanding of metals and the importance of their structures and technical characteristics. Particularly fertile during the 1890s was his relationship with the Institution of Mechanical Engineers, which body, in 1889, started a research committee to extend investigations he had already made into the effects that small proportions of impurities produced in the physical and mechanical properties of metals. During the ten years which followed, five reports were presented to the Institution of Mechanical Engineers, embodying the results of the experimental work together with descriptions of new techniques which Roberts-Austen and his collaborators had adopted. Awareness of these techniques came from his lively contacts with workers in a wide field. The prosecution of these investigations afforded a handful of young metallurgical graduates an opportunity to gain experience in 'research' into metallic structures and properties, and thereby to extend the frontiers of knowledge. Like his predecessor, Roberts-Austen wrote a textbook, modestly entitled An introduction to the study of metallurgy.⁽¹⁰⁾ However, unlike Percy's discursive, multiple-volume work in which each of the common metals was considered in turn, Roberts-Austen's book took as the basis of its chapters topics such as 'alloys', 'the thermal treatment of metals', 'materials and products of metallurgical processes', and 'typical metallurgical processes'.

The third of the metallurgy teachers at the Royal School of Mines to make an outstanding contribution to metallurgical instruction was Dr. H.C.H. Carpenter (b.1875-d.1940), who was appointed to the chair in 1913 and retained the position at the time of his death twenty-seven years later. Born into fortunate cultural and financial circumstances, Carpenter obtained first-class honours in chemistry at Oxford in 1896 and then studied in Leipzig for his Ph.D. degree in organic chemistry. He then went to Owen's College in Manchester, but in 1902 was appointed head of the two departments of chemistry and metallurgy at the new National Physical Laboratory in Teddington, where he was soon involved in work on thermal transformations in the iron-carbon system and in the study of high-speed tool steels. Some of the work done at

(10) ROBERTS-AUSTEN, W.C., An introduction to the study of metallurgy.
(London: Charles Griffin, 1st edn. 1891), 292pp.

the NPL at that time was an extension of that of the Alloys Research Committee of the Institution of Mechanical Engineers, in which Roberts-Austen had been so closely engaged.

In 1906 at the age of 31, Carpenter was invited to occupy the newly-created chair of metallurgy and metallography in the Victoria University of Manchester. In the following seven years, as his successor later wrote, 'he built up the department from zero, and under his inspiring guidance this school quickly became known as a flourishing centre of research'.⁽¹¹⁾ The first research publication dealt with 'the complex problem of the growth of cast iron after prolonged heating or repeated heating and cooling', a subject having wide practical application in, for example, the case of buildings partly constructed of cast iron which were subjected to fire damage.⁽¹²⁾ At the age of 38, in 1913, Carpenter was appointed to the chair of metallurgy at the Royal School of Mines; at the outset of his tenure of this post he undertook a six-months' tour of metallurgical works and centres of research in the USA and Canada. For the next twenty-six years, until his unexpected death from heart failure in 1940, Carpenter was in the forefront of British metallurgical teaching and academic research, raising standards, extending knowledge, inspiring students. Nonetheless, among the undergraduate students at the Royal School of Mines in the 1920s he was remote, leaving to one of his assistant professors the important task of maintaining contact.⁽¹³⁾ Perhaps above all, Carpenter's chief contribution was as an ambassador, promoting amongst those with whom he came into touch in Governmental committees and at meetings of learned societies the idea that those connected with metallurgy might be respectable and scientific.

In 1908, while he held the chair at Manchester University, Carpenter took a leading part in the successful launching of a new learned society, the Institute of Metals, intended to provide meetings to discuss original researches relating to non-ferrous metals, together with a journal in which they could be

(11) EDWARDS, C.A., 'Henry Cort Harold Carpenter 1875-1940'.
Obit. Notices Fellows Royal Soc. (London), 1939-41,
vol.3, 617-618.

(12) EDWARDS, C.A., op.cit., 618.

(13) KENNETT, S.J., personal communication, 1982. Dr. Kennett took the undergraduate metallurgy course at the Royal School of Mines, 1923-26.

published. He devoted time and energy to winning over influential people to support the proposed society, and served as honorary secretary during the first two years of its existence. Later he became vice president, and then served as president for two years. In addition, he was president of the Institution of Mining and Metallurgy for 1934, and of the Iron and Steel Institute for the two succeeding years. For six years he was a member of the advisory council of the Department of Scientific and Industrial Research, and was chairman of the council's metallurgical advisory board for the whole of the ten or twenty years of its existence. Moreover, he sat on the executive council of the National Physical Laboratory. Professor Carpenter was elected a Fellow of the Royal Society in 1918 and for some time served on that body's council. Clearly, his contacts on all these committees provided many opportunities for influence.

On the occasion of the first Empire Mining and Metallurgical Congress, held at Wembley in 1924 as part of the wider British Empire Exhibition, Carpenter presented a comprehensive account of 'Metallurgical education of university rank in Great Britain' which he had compiled with the help of contributions from those in the various departments concerned:⁽¹⁴⁾ at that time, eleven departments offered undergraduate courses leading to degrees in the subject, while Cambridge provided postgraduate facilities. In his opinion, the facilities for metallurgical training were 'very considerable and ... ample'. He observed that⁽¹⁵⁾

'Since metallurgical departments are expensive to found and to maintain, any further resources which may become available for education and research should be devoted, not to establishing new departments, but to strengthening and extending existing ones.'

This was at a period when two new metallurgy departments had just opened, at the University of Liverpool and in University College Swansea, and all the departments together probably had no more than 40 or 50 undergraduate students between them. By some means or other, the departments all contrived to remain open throughout the 1930s, and by the later 1940s were able to justify their

(14) CARPENTER, H.C.H., 'Metallurgical education of university rank in Great Britain'. Proc.(First) Empire Mining Metall. Congress (1924). part 5 non-ferrous metallurgy, (London: 1925), 43-79.

(15) CARPENTER, H.C.H., op.cit., 47.

presence. However, with the ineptitude that seems to characterise the handling of British public affairs, a number of new university departments of metallurgy was then allowed to come into being, unmindful of the experience of the inter-war period.

Three years after the Wembley empire congress, Professor Carpenter delivered the annual James Forrest lecture to the Institution of Civil Engineers, taking as his title, 'Some recent services of metallurgy to engineering'.⁽¹⁶⁾ Two years later again, in 1929, he received a knighthood for 'his contributions to science and metallurgy, and his many varied services to his country'.⁽¹⁷⁾ By his metallurgical researches he received international recognition: he was a corresponding member of the Royal Swedish Academy of Science and of the French Société d'Encouragement.⁽¹⁸⁾ He received gold medals from German steelmakers and from the American Institute of Mining and Metallurgical Engineers and, strangely in 1940, the Honda Gold Medal from the Japanese Institute of Metals. No fewer than fifteen papers of which he was either sole or joint author were published in the Journal of the Iron and Steel Institute. One further way in which H.C.H. Carpenter promoted metallurgical instruction was as co-author of a pair of monumental volumes entitled Metals, which covered nearly 1500 pages; in 1940 they were described as 'the most comprehensive work dealing with the properties of metals that has ever been written in the English language'.⁽¹⁹⁾ There seems little doubt that Dr. Carpenter's high standing as a technological investigator, coupled with his personal characteristics, helped to enhance the reputation of the metallurgy departments with which he was associated and to lead to general acknowledgement that a field of study existed.

Between them, Percy, Roberts-Austen and Carpenter were involved with the teaching of metallurgy over a span of more than 85 years of the century 1851 - 1950. Another teacher with 'personality' was John Oliver Arnold (b.1858-d.1930). He came into the field of metallurgical instruction nearly forty years

(16) CARPENTER, H.C.H., 'Some recent services of metallurgy to engineering'.
Mins.Proc.Instn.Civil Engrs., vol.224 (1926-27), pt.2, 291-341.

(17) EDWARDS, C.A., op.cit., 624.

(18) ANON., 'Obituary: Sir Henry Cort Harold Carpenter, FRS'.
Jrnl.Iron Steel Inst., vol.142 (1940), no.2, 291-293.

(19) EDWARDS, C.A., loc.cit.

on from 1851 when, in 1889 at the age of thirty-one, he was appointed at a salary of £250 a year to the chair of metallurgy at Sheffield Technical School; at this time the venture had been in existence for half-a-dozen years and was ripe for expansion. During the next fifteen or twenty years of the thirty that Arnold occupied the post he was influential in making the subject of metallurgy known, particularly among steelmakers. He recruited numerous students to his courses, and secured greatly-increased teaching facilities in Sheffield. Arnold's previous experience, following secondary education at King Edward VI School in Birmingham, included a naval cadetship involving a voyage to India, and ten years' employment in iron-and-steel companies in Sheffield and Leeds. Shortly before embarking upon his teaching work he had been awarded the Telford Premium of the Institution of Civil Engineers for his paper on the influence of chemical composition in steel tyres.⁽²⁰⁾ In his academic post he successfully established the study of metallurgy in the Sheffield area. Energetic and determined, he knew how to carry out chemical analyses of the constituents of steel, and was regarded as a skilful manipulator. Presumably also he spoke the language of the local steelmakers; he acquired a reputation as a useful industrial consultant, and the numbers of students who came from the local works for evening-class study grew substantially. Arnold championed the cause of the evening-class students, and was proud of the fact that, up to 1905, almost equal numbers of day and evening students (20 and 19 respectively) had won the college's Associateship in Metallurgy. Between 1889 and 1905, staff and students of the metallurgical department published 'about thirty original researches'. Around 1890, and again on grander scale immediately prior to the inauguration of the autonomous University of Sheffield in 1905, new facilities were provided for the engineering departments of the college, including metallurgy. Professor Arnold was a proponent of the philosophy that in a teaching establishment for a technological subject like metallurgy the equipment should resemble that of a works, being capable of doing things as in industry, albeit on modest scale. Thus, in the session 1904-05, 'over 40 tons of ingots and castings were made'.⁽²¹⁾

(20) ANON., 'Professor John Oliver Arnold'. Page's Weekly, vol.6 (24 March 1905), 633.

(21) ARNOLD, J.O., 'The department of iron and steel metallurgy at the University of Sheffield'. Jrnl.Iron Steel Inst., vol.58 (1905), no.2, 23.

With the establishment in 1905 of the University of Sheffield, it became possible to award degrees in metallurgy at three levels: B.Met., M.Met., and D.Met. Twelve years later, in 1917, and appropriately for a steel town, the subject of metallurgy at Sheffield was given a university faculty to itself; when the second half of the twentieth century duly opened, this was to remain the only instance of a faculty of metallurgy among the dozen British university departments that offered the subject as a major branch of instruction. We can be sure the determined personality of Arnold had a good deal to do with the realisation of this distinction.

During the 1890s Arnold tried to elucidate the fine details of, as well as the reasons for, the observed behaviour of iron-carbon alloys which formed the important range of bulk steels. In the course of the investigations he made considerable use of the new technique of metallography. He was responsible for several published articles which considered the topic of steel structures, and it was his work in this field which made his name (and voice !) recognised in the international arena. Soon after 1900 Arnold was awarded the Bessemer gold medal of the Iron and Steel Institute, but by this date already some of his published writings and uttered statements had been left behind by the growth of knowledge. Nonetheless, in 1912, he was elected to Fellowship of the Royal Society. In 1905, as one of three technologists, he accompanied the British Association to South Africa as a special lecturer on steel. He was a member of the standing committee on metallurgy of the advisory council of the Privy Council, and was 'frequently consulted' by the Admiralty.⁽²²⁾

Besides numerous steelmakers, Arnold's products included at least three students who, in their turn, became notable teachers of metallurgy: F.C. Thompson (professor at Manchester), L. Aitchison (lecturer and later professor at Birmingham), and H. O'Neill (professor at Swansea). However, in the view of at least one commentator who was a full-time undergraduate at the time, in the years around 1910 the teaching in Arnold's department was in a poor state: in similar manner to the situation that prevailed in the metallurgy department of the Royal School of Mines one or two decades later, the professor seemed

(22) ANON., 'Obituary: Professor John Oliver Arnold, FRS'.
Jrnl.Iron Steel Inst., vol.122 (1930), no.2, 391-392.

remote from students, and they derived much more information and inspiration from the supporting staff.⁽²³⁾

One other academic to be mentioned is Dr. Robert Salmon Hutton (b.1876-d.1970). Unlike those considered so far, each of whom held a leading academic post for more than twenty years of his life, Dr. Hutton occupied a professorial chair in metallurgy for no more than thirteen years, following a wide range of other experience; the reasons for his inclusion here chiefly lie outside his academic achievements, relating directly to his energetic campaigning for better, and enlarged, facilities for metallurgical instruction. Hutton was nearly 55 years of age when appointed in 1932 to the chair of metallurgy in the University of Cambridge. It is true that earlier, between 1900 and 1908, he had been lecturer on electrometallurgy in the University of Manchester, before entering the family silver-cutlery business in Sheffield. When this collapsed at the end of the Great War, he became the first director of the British Non-Ferrous Metals Research Association, one of the new organisations arising from the policy of the Department of Scientific and Industrial Research. As director, Dr. Hutton tried by various means to promote efficiency within the industrial units which comprised the association, one method being by publicising accounts of fresh developments likely to lead to economies in working. Aware of the difficulties of keeping up with the flow of information coming from newly-published articles and books, and of the problems in achieving efficient communications, he was instrumental in bringing about the formation of ASLIB, the Association of Special Libraries and Information Services, in 1924.⁽²⁴⁾ During the 1920s he travelled an estimated average of 1600 km (1000 miles) a week, trying to keep in touch with member companies and also with new developments in the USA, France and Germany, as well as within Britain.

Not only did this experience stand him in good stead in 1931-32, when he was elected to the newly-created chair of metallurgy in the University of Cambridge, endowed by the Worshipful Company of Goldsmiths, but it enabled him to form a good idea of the scale of the needs for fresh metallurgical graduates, and to compare the situation in Britain with those prevailing in

(23) THOMPSON, F.C., 'Reminiscences'. The Metallurgist, vol.3, no.10 (Aug. 1968), 224.

(24) HUTTON, R.S., Recollections of a technologist. (London: Sir Isaac Pitman, 1964), 162-163.

the USA and on the Continent of Europe. At the end of 1937 Dr. Hutton addressed two meetings in London on the need for greater numbers of metallurgical graduates, pointing out that, at the time, the total British honours graduates ranged from fourteen to twenty, compared with about 400 graduates in chemistry. Even allowing for the fact that a high proportion of chemistry students would enter teaching rather than industry, the imbalance in numbers was striking. Its significance was heightened by Hutton's remark that the British metallurgical industries produced output valued at nearly five times that of the chemical industries.⁽²⁵⁾ The supply of British trained metallurgists he considered compared unfavourably with the situation in Germany.

This arousal of interest in the state of British metallurgical instruction was timely, and in the years that followed considerably greater publicity was given to the subject. It was Hutton who initiated discussion on the matter, and it is not without significance that he was widely travelled, both in the USA and in Germany: twice in the 1930s, in 1933 and again four years later, he delivered lectures before learned societies in the USA. He had German friends, for example Dr. Paul Rosbaud, who worked as scientific editor for the publishing company of Springer in Berlin and formerly edited Metallwirtschaft. Moreover, Dr. Hutton's views may well have been influenced by the atmosphere that prevailed in Cambridge around 1937, where there was great awareness of the likelihood of war in the near future, and apprehension over the relative weakness and vulnerability of the British technical economy.

Within the University of Cambridge, Hutton was responsible for expansion of the metallurgical research facilities and for successful organisation of the first undergraduate teaching in the subject. Metallurgy became recognised for the honours degree, the first part II examinations being held in June 1938, and the first part I metallurgy examinations in the Natural Science Tripos being offered in 1943.⁽²⁶⁾ Through his associations with the Goldsmiths' Company, in 1939 Hutton was elected chairman of council of the City and Guilds of London Institute, an office he held until 1950.⁽²⁷⁾ In this capacity he served on the governing body of the Imperial College of Science and Technology, of which the Royal School of Mines with its department of metallurgy

(25) HUTTON, R.S., op.cit., 83.

(26) HUTTON, R.S., op.cit., 85.

(27) HUTTON, R.S., op.cit., 113.

formed a part, and at the same time, during the 1940s, took an active role in promoting national developments in technical instruction. For instance, in July 1942 a deputation from the City and Guilds' Institute met the president of the Board of Education, R.A. Butler, at a time when the Education Act of 1944 was being planned. This visit resulted in closer co-operation with the Government office than had existed previously. When the Government's White Paper, Educational reconstruction, was issued in July 1943, Hutton considered that its proposals for improvement and financing of technical education appeared wholly inadequate. Accordingly, he set to work, and by December of 1943, when the Education Bill was presented to Parliament, the City and Guilds' Institute had published a critical review which included a supplement by Hutton of 'the position of technical education in this country and abroad ... making definite proposals for improvements, particularly in relation to technological education of university rank.'⁽²⁸⁾ Critical comments were also submitted to Government by other bodies, and it seems likely these concerted representations had some effect upon the politicians, for technical education was given a high priority instead of being left at the bottom of the queue, and a financial provision of £35 million was asked for in place of the original £2½ millions.⁽²⁹⁾ A few months later, a Government committee on higher technological education, the Percy committee, was brought into being. In 1947, just when the Parliamentary and Scientific Committee was preparing to issue its report on Colleges of technology and technological manpower, Hutton returned to the attack in a review which was published by the City and Guilds' Institute, Some problems of higher technical education; in this he particularly stressed 'the urgent importance of improvements both quantitative and qualitative in the education of technologists'.⁽³⁰⁾

Dr. R.S. Hutton was an active campaigner in the corridors of political power. By the nature of things, any politicians who took up the cause of technical education with significant effect did so over a wide front rather than on a narrow subject basis. In parenthesis, however, it is intriguing to speculate what the status of the metallurgist in Britain might have become had

(28) HUTTON, R.S., op.cit., 124.

(29) HUTTON, R.S., loc.cit.

(30) HUTTON, R.S., op.cit., 125.

it been championed by even a single dedicated national politician. As it was, the whole-hearted advocates of even generalised technological encouragement were few: in the nineteenth century Bernhard Samuelson MP stood out strongly, while in the first half of the twentieth century Lord Eustace Percy MP made some impact, although in his case it was not until after he had forsaken politics that he was afforded the principal opportunity to exercise his views influentially.

Bernhard Samuelson (b.1820-d.1905), and his fellow ironmaster and contemporary Isaac Lowthian Bell (b.1816-d.1904), have been repeatedly used as examples of the fascinating breed of 'enlightened' industrialists with social conscience, the views and opinions of both being made widely accessible by the publication of Parliamentary Reports to which they contributed. Samuelson came to public notice in 1867 as the result of his writing a long letter to the vice president of the Committee of Council for Education, urging reforms in the British educational system. The following year he was chairman of the Parliamentary Select Committee on Scientific Instruction. In 1870-75 he was a member of the Royal Commission on Scientific Instruction and the Advancement of Science, which sat under the chairmanship of the Duke of Devonshire. A decade later, in 1881-84, Samuelson was chairman of the Royal Commission on Technical Instruction. The fact that he made his living from iron and agricultural implements seems largely irrelevant to his conscientious expenditure of time, money and effort in pursuit of better technological education for the benefit of Britain. Locally, he gave generously, to the extent of several thousand pounds, for the creation of a high school in Middlesbrough and for the starting of science classes, even though in the 1880s he was unsuccessful in his attempts to establish in the town a 'metallurgical school'.⁽³¹⁾ Apart from this, he does not seem to have been directly interested in promoting metallurgical instruction as such.

I.L. Bell was a leading witness in several Parliamentary inquiries, and moreover had the ability to publish his views. He was author of the book The chemical phenomena of iron smelting, published in 1872; this influenced

(31) POTTS, A., 'The educational work of Sir Bernhard Samuelson (1820-1905), with special reference to technical education.' Unpublished M.Ed. thesis, University of Durham (1969), 44; quoting circular 'Proposed technical school for Middlesbrough' (Nov. 1882).

thoughts and practice for the remainder of the nineteenth century. He was one of the main people involved with the successful formation of the Iron and Steel Institute. In his presidential address to the institute in 1873 Bell observed that 'the cultivation of metallurgical science has been much more industriously pursued abroad than has hitherto been the case in this country'.⁽³²⁾ However, it was Bell's elder son, Thomas Hugh Bell, who was the consistent champion of educational provisions in Middlesbrough throughout the period 1870 - 1910, serving on local boards and development committees, and contributing to subscription lists.

While the Bells, father and son, were always primarily industrialists, albeit educated ones, their fellow northcountryman Lord Eustace Percy (b.1887-d.1958) was born half a century later a member of the aristocracy. After experience in the diplomatic service, Percy was elected Conservative MP for Hastings in 1921, and in Stanley Baldwin's new government of November 1924 was appointed president of the Board of Education with a seat in the cabinet. During his tenure of the presidency, which ended with the general election of 1929, he worked to secure the wider recognition of technical instruction; this was a time when severe financial restraints on the scale of Governmental educational spending were imposed by his colleagues and, in some districts at least, young people were growing up in an environment of high unemployment. While generally pursuing the national educational aims set out by his immediate predecessor, Charles Trevelyan, and pleased to have the support for changes in general schooling which came with the publication in 1926 of Sir William H. Hadow's report on Education of the adolescent, Percy was at odds with the concept of widespread but restrictive education for all to a mediocre level of attainment. For one thing he seems to have disliked the 'anti-vocational' trend which was fashionable in the 1920s, and for another he felt it important to provide opportunities for those who wanted to gain more education. In contrast with the Hadow committee, Percy considered vocational training was a part of the educational field which needed to be strengthened and enlarged; he therefore did his best 'to revive national interest in technical education, and to encourage more regional consultation in its development'.⁽³³⁾ As part of this strategy, he had reprinted the

(32) CARR, J.C., and TAPLIN, W., History of the British Steel industry. (Cambridge, Mass.: Harvard Univ.Press, 1962), 48.

(33) PERCY, Eustace, Some memories. (London: Eyre and Spottiswoode, 1958), 101.

chapter entitled 'Survey of technical education in England and Wales' which appeared in the Annual report of the Board of Education for the year 1924-25.⁽³⁴⁾ Likewise at his behest, following the general strike of 1926, the Board of Education undertook surveys of individual industries and industrial districts to assess their likely needs for technical instruction: of particular relevance here is the survey published in 1930 of the West Midlands metal-working area, where a fair proportion of the country's metallurgical industry was concentrated.⁽³⁵⁾

Losing office with the return of a Labour Government in June 1929, Percy took the opportunity to set down in written form some of his views; these were published in 1930 under the title Education at the crossroads.⁽³⁶⁾ Within the national educational framework, this book argued in favour of substantial change and improvement in the position of technical colleges. In the prevailing circumstances, Percy regarded such actions as more important than the general raising of full-time school-leaving age. He suggested there was considerable need for the technical colleges to take greater part in the development of local educational facilities. He believed their value would be enhanced if they acquired the character of 'local colleges', in which evening-class activities in adult education were combined with technical and other vocational instruction to assist in teaching independence of judgement. He was pained by the second-class status accorded to 'technical colleges', which he saw as potentially the local equivalents of the established universities. He propounded the view that technical colleges and universities should regard themselves as equals as far as technological expertise and experience was concerned, and that the universities should help the 'local colleges' to become the leaders for their own districts.⁽³⁷⁾

At the time, little notice was taken of these proposals, and in 1937

(34) BOARD OF EDUCATION, Survey of technical and further education in England and Wales. (HMSO, 1927), Board of Education, educational pamphlet no.49.

(35) BOARD OF EDUCATION, Education for industry and commerce. The West Midlands metal working area. (LONDON: HMSO, 1930), Board of Education, educational pamphlets no.74 (industry series, no.7).

(36) PERCY, Lord Eustace, MP., Education at the crossroads. (London: Evans Brothers, 1930).

(37) PERCY, Lord Eustace, MP., op.cit., chap.6 'Universities and local colleges as partners', 91-104.

Lord Eustace Percy left politics, becoming rector of King's College, Newcastle-upon-Tyne. During his fifteen years as rector he contributed to the well-being and growth of the Newcastle division of the University of Durham, and hence to the improvement of facilities for technological instruction in North-eastern England. More importantly for present purposes, however, in 1944 he was invited by the Minister of Education to become chairman of a departmental committee on higher technological education asked 'to consider the needs ... (for such) education in England and Wales and the respective contribution to be made thereto by Universities and Technical Colleges' with reference to the requirements of industry.⁽³⁸⁾ The findings of this committee, published in 1945 and becoming widely known as 'the Percy report', influenced subsequent Governmental actions relating to higher technological instruction. Reiterating the view put forward by Percy fifteen years before in Education at the crossroads, the committee's report pointed to 'the greatest deficiency in British industry ... the shortage of scientists and technologists who can administer and organize, and can apply the results of research to development'.⁽³⁹⁾ It reported evidence of serious shortcomings in both the quantity and the quality of men entering industry following periods of training in the universities and technical colleges. Among its recommendations, the Percy report advocated the fostering of high-level technological instruction at a number of selected technical colleges, and the nation-wide monitoring of rational course provisions by means of regional advisory councils. It was largely arising from the Percy committee's recommendations that, in the five years before 1950, there were to come into existence a National Foundry College and the College of Aeronautics at Cranfield. In both these institutions metallurgical instruction was to feature significantly, as it was in several other developments of the second part of the present century which were to materialise with the help of the Percy report. In short, a definite link can be traced between these later improvements in the facilities available for technological training and Lord Eustace Percy's ideas, which probably crystallised while he was actively handling the problems

(38) MACLURE, J. Stuart, Educational documents England and Wales 1816 to the present day. (3rd edn., 1973), 226.

(39) PARSONS, S.A.J., The framework of technical innovation. (London: Macmillan, 1968), 141.

of national education in the 1920s, and which he committed to paper in 1930.

Lord Eustace Percy tried to bring about the changes he considered desirable by means of personal contacts and persuasion, coupled for a time with political authority. However, more potent than any political eloquence is the possession of money: during the hundred-year period 1851 - 1950 finance on a large scale for the promotion of metallurgical instruction came from a handful of individuals of whom the most easily identified are Andrew Carnegie and Sir Robert A. Hadfield. Andrew Carnegie (b.1835-d.1919), the Scottish emigrant to Pennsylvania, had become by 1881 'the foremost iron-master in America'. Twenty years later, when he sold the Carnegie Steel Company and retired from business, he was credited with more than £60 million.⁽⁴⁰⁾ Carnegie's encouragement of British metallurgical scholarship took practical shape in 1901, while he was vice president of the Iron and Steel Institute. He presented the institute with 64 thousand-dollar, five-per-cent. debenture bonds in the Pittsburg, Bessemer and Lake Erie Railroad Company for the purpose of awarding annual scholarships to support researches 'in the metallurgy of iron and steel and allied subjects, with the view of aiding its advance or its application to industry'. There was no restriction on sex or nationality, and the only constraint upon the place of research was that it should be adequately equipped to carry out metallurgical investigations.⁽⁴¹⁾ Each scholarship was worth £100 a year, and within a year or two of the scheme's inception Carnegie provided additional funds so that the number of scholarships could be increased from three to six. Besides the support grants, the scheme made provision for awarding the Andrew Carnegie Gold Medal to the participant who submitted a report of sufficient merit. It is interesting to note that in 1905 the six-man Carnegie scholarship committee of the Iron and Steel Institute included R.A. Hadfield, G.J. Snelus ARSM FRS, and J.E. Stead FRS.⁽⁴²⁾ Hadfield was himself to be an outstanding financial encourager during the period 1915 - 1935; Snelus was a respected steelmaker who had been closely associated with technological developments for the previous

(40) CUNNINGHAM, A.S., 'Carnegie, Andrew'. Dict.Nat.Biography, 1912-21. (London: Oxford Univ.Press, 1927), 92.

(41) ANON., 'The Andrew Carnegie research scholarship'. Proc.Cleveland Instn.Engrs., (1901-02), 30.

(42) Page's Weekly, vol.6 (19 May 1903), 1056.

thirty years and had at one time been one of the Government's select band of 'science teachers'; Stead of Middlesbrough was extremely active in metallurgical research, trained a succession of successful 'metallurgical chemists', and was a staunch advocate of improved facilities for instruction.

Throughout the first half of the twentieth century the Carnegie scholarships scheme was an important means for fostering metallurgical research in Britain; many people who afterwards came to occupy responsible positions, including academic ones, benefited from it, and the reports of investigations contained some notable advances in knowledge. For these reasons, Carnegie's benefactions merit high recognition. Additionally, it may be safely assumed that the cause of metallurgical instruction was helped by the twelve-million dollars Carnegie gave for endowment of 660 libraries in the British Isles.⁽⁴³⁾ Around 1920, Dr. J.E. Stead claimed that Carnegie had agreed to provide money for starting a metallurgical centre in Middlesbrough, but died before anything could come of the promise.

To a considerable extent, as far as British metallurgy was concerned, the mantle of Carnegie was assumed by Robert Abbott Hadfield (b.1858-d.1940). In the early 1870s Hadfield's father had established successful steel-casting works in Sheffield, and the younger man received a good start, entering the business in 1875. Although he lacked any formal training in research, he began systematic practical metallurgical investigations which led to the development of alloy steels, his own 'Hadfield's manganese steel' being a noteworthy new variety in the closing years of the nineteenth century.⁽⁴⁴⁾ Hadfield became widely recognised as a leading metallurgical researcher as well as a successful and energetic industrialist, and over many years he was a vociferous champion of the importance of metallurgy, while his financial help was of substantial practical value during the 1920s and 1930s. To the University of Sheffield between 1917 and 1935 Hadfield gave altogether sums of at least £27 000 for improvements in the facilities for studying metallurgy and foundry work; new laboratories, bearing his name, were opened in 1938. Among his published volumes were The work and position of the metallurgical chemist (printed privately in 1921) and Metallurgy and its influence on modern

(43) CUNNINGHAM, A.S., loc.cit.

(44) ANON., 'Obituary. Sir Robert Abbott Hadfield, Bart., D.Sc., FRS'.
Jrnl.Iron Steel Inst., vol.142 (1940), no.2, 285P.

progress (London: Chapman and Hall, 1925). Both books were effusive and wide ranging.

In the 1920s Sir Robert Hadfield (as he had become in 1917) endowed a scholarship, preferably for English subjects, tenable at the Metallografiska Institutet in Stockholm. In 1927, finding himself unable to take part in the second Empire Mining and Metallurgical Congress which was to be held in Canada, he offered two travelling scholarships, each with a value of £200, to help others to attend. The election of the scholars was determined by the Institution of Mining and Metallurgy and the Iron and Steel Institute, who made awards to Assistant Professor Bernard W. Holman (of the mining staff at the Royal School of Mines) and Miss Constance Elam (a leading metallurgical research worker at both the National Physical Laboratory and the Royal School of Mines).⁽⁴⁵⁾

In the closing years of the hundred-year period 1851 - 1950, important financial encouragement for metallurgical training came from two quarters, one a charitable trust and the other a commercial company. Both, however, are clearly associated with particular individuals. The trust was associated with William Richard Morris (b.1877-d.1963), Viscount Nuffield who, from 1938, made donations and bequests totalling more than £28 millions;⁽⁴⁶⁾ to facilitate the distribution of these gifts, in 1943 the Nuffield Foundation was established with £10-million worth of Morris Motors' stock. A large proportion of the total sum donated went for medical and social endeavours, but a useful amount was directed by the Nuffield Foundation into metallurgy. According to one account,⁽⁴⁷⁾ it was 'Lord Nuffield's personal and keen interest in extraction metallurgy' which

'led directly to the decision of the trustees of the Nuffield Foundation in 1946 to devote £70 000, to be spent over a period of five years in some way which would be of benefit to metallurgical education and research in the British Empire.'

It happened that the secretary of the Nuffield Foundation, L. Farrer Brown,

(45) ANON., 'The Hadfield travelling scholarships'.
Mining Mag. (London), vol.37, (Sep.1927), 130-131.

(46) HOLDER, D.W., 'William Richard Morris, First Viscount Nuffield'.
Biograph. Mems.Fellows Royal Soc.(London), vol.12 (1966), 397.

(47) INSTITUTION OF MINING AND METALLURGY, 'Report of fifty-eighth annual general meeting of the institution' (19 May 1949).
Trans.Instrn.Mining Metall., vol.58 (1948-49), 32-33.

was an old friend of a leading member of the London Metallurgical community, Dr. J.H. Watson of the Royal Mint and, ⁽⁴⁸⁾ as a result of Dr. Watson's proposals, the Institution of Mining and Metallurgy became involved, and a scheme was agreed. Travelling scholarships and fellowships were made available in 1947 and for a number of the following years, with the primary aim of enabling undergraduate students, postgraduates, and metallurgical teachers to broaden their experience by visiting industrial plants situated in other parts of the world. At the same time funds were allocated for a research fellowship in extractive metallurgy, tenable for five years at the Royal School of Mines; this developed into the Nuffield Research Group which during the 1950s was to afford training to a number of investigators and to make important contributions to the extension of knowledge.

The industrial organisation which supplied handsome sums to aid metallurgical training was the International Nickel Company of Canada, and its subsidiary in Britain, the Mond Nickel Company. In 1937, D. Owen Evans MP, vice president of the International Nickel Co. and chief executive in Britain of Mond Nickel, was instrumental in providing the Institute of Metals with a platinum medal 'to be awarded annually for distinguished work in any branch of non-ferrous metallurgy'. ⁽⁴⁹⁾ Nine years later, in 1946, the then chairman and managing director of the Mond Nickel Company, Sir William T. Griffiths, addressed letters to the presidents of the five organisations in Britain concerned nationally with metallurgy, offering to provide fellowships. He had persuaded his fellow directors of the Mond Nickel Company to supply, under a seven-year covenant, a total sum of £50 000; this money was to be made available to the five national organisations in such a way that five fellowships, of an average value of £700, could be awarded each year for between ten and fifteen years. It was intended the awards should be made to men and women of British nationality who were already educated to degree level and who wished to spend a year, generally abroad, in studying some aspects of metallurgical industry. The objects of the scheme were to improve the application of research findings to British metal-using and metallurgical industries; to assist those with qualifications in metallurgy to obtain training that would help them to assume executive and administrative positions in industry; and

(48) WATSON, Dr. J.H., personal communication, Dec. 1981.

(49) The Metal Industry, vol.50, no.11 (12 Mar. 1937), 343.

to attract into the metallurgical field those qualified in other branches of science.⁽⁵⁰⁾ The first year of the awards was 1947. In 1949 only two Mond Nickel Fellows were appointed.⁽⁵¹⁾

From a small number of sources, and inspired by individuals, came considerable sums of money to promote metallurgical instruction. One or two other people found it possible to achieve much through personal effort and involvement. One person who made an outstanding contribution by sustained personal effort was J.W. Jenkin (b.1899-d.1974). At the end of the Great War, John Watson Jenkin obtained a grant of £156 a year from the Board of Education to take a two-year course leading to an honours degree in chemistry at King's College London. He then studied metallurg for eighteen months on an extended grant at Sheffield, emerging in 1923 as the possessor of the University's first Ph.D. in the subject.⁽⁵²⁾ After several years' metallurgical work at the National Physical Laboratory, in 1929 he began employment with a Midland company, Tube Investments Ltd., where, during the next 35 years, he built up from scratch a large research organisation, becoming director of technical information. Dr. Jenkin soon became involved with the Midland metallurgical societies, being hon. secretary of the Birmingham section of the Institute of Metals from 1931 to 1938, and chairman of the section in 1944-45.⁽⁵³⁾ He also served on the council of the Birmingham Metallurgical Society, being president in 1945-46.⁽⁵⁴⁾ In 1944 he became a member of the joint committee on national certificates in metallurgy, assuming the chairmanship of the committee in 1949. In 1947 he joined the committee set up to administer the new Mond Nickel Fellowships, becoming chairman in 1950.⁽⁵⁵⁾ During the

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- (50) GRIFFITHS, W.T., 'Fellowships in metallurgy' (copy of letter from the chairman of the Mond Nickel Co. to the president of the Institution of Metallurgists, 27 Feb. 1946). Bull.Instn. Metallurgists, no.1 (July 1946), 16-18.
- (51) ANON., 'Mond Nickel Fellowships'. Bull Instn.Metallurgists, vol.2, no.4 (Dec. 1949), 43-44.
- (52) JENKIN, J.W., '50 years in metallurgy'. Metallurgist Materials Technologist, vol.5 (Nov.1973), 579-582.
- (53) JENKIN, J.W., 'The presentation of metallurgical information'. Originally published by The Metal Industry (1958), with reprints issued by the Department of Technical Information, Tube Investments Ltd., Birmingham (1958), with biographical note extracted from The Birmingham Post year book 'who's who'.
- (54) WEST, E.G., 'Dr. J.W. Jenkin - an appreciation'. Metallurgist Mats.Technologist, vol.7 (Feb.1975), 102.
- (55) JENKIN, J.W., loc.cit.

late 1940s he served on the City and Guilds' advisory and moderating committees on metallurgy as well as on the City of Birmingham's education committee on metallurgy. ⁽⁵⁶⁾

In 1943, following the suggestion made by Dr. Marie L.V. Gayler of the National Physical Laboratory, Jenkin was one of those who took steps to form a professional body to represent metallurgists, being in the forefront of negotiations which, late in 1945, led to the establishment of the Institution of Metallurgists. The following year he was elected the institution's second president, a position he held until 1948. In this capacity he influenced the style adopted by the new institution and the matters which it considered important; these included a reasonable level of wages offered to metallurgists by employers, a high standard of competence and integrity, and improved status. To ensure a continuing high standard of competence among the rising generation meant providing increased facilities for metallurgical instruction at various levels; from the outset, the Institution of Metallurgists took positive interest in metallurgical instruction. Besides participation in the joint educational committee of the Iron and Steel Institute, the Institution of Mining and Metallurgy, and the Institute of Metals, the Institution of Metallurgists drew up its own plans for written and oral metallurgical examinations to qualify for membership. The first of these examinations were held in 1947; Dr. J.W. Jenkin was chairman of the examinations board until 1952. His presidential address to the Birmingham Metallurgy Society in 1945 was published under the title 'Metallurgy as a profession', while a year later parts of an address he delivered to the Sheffield Metallurgical Association were published with the question 'Whither Metallurgy?'. ⁽⁵⁷⁾

Interviewed some twenty-five years later, Dr. Jenkin affirmed his view that a professional person 'should be desperately keen on his work - to the point of sacrifice, if necessary - and should maintain the highest standards of competence and conduct.' He commented that 'only if the individual job satisfaction of the worker is of the greatest will the status of a profession be enhanced.' On the need for flexibility to enable the metallurgist to make

(56) IRON AND STEEL INSTITUTE, 'John Watson Jenkin, Ph.D., ARIC, FIM'.
Jrnl. Iron Steel Inst., vol.158, pt.3 (Mar.1948), frontis.

(57) JENKIN, J.W., 'Metallurgy as a profession'. The Metal Industry,
vol. 67 (23 Nov.1945), 335-337;
(30 Nov.1945), 362-364.

JENKIN, J.W., 'Whither Metallurgy?'. Metallurgia, vol.35, pt.205
(Nov.1946), 41-46.

major changes in professional activities in mid career, he believed that among the chief qualifications likely to help was possession of a 'good groundwork in metallurgy', while 'most of all, personality counts, with an ability to communicate.'⁽⁵⁸⁾ These were the opinions of a man whose academic introduction to metallurgy had been made through eighteen months' postgraduate study for a Ph.D. degree, and who subsequently, during a long career involving metallurgical and management skills, had devoted much energy to improving the status of the subject.

In this chapter, the influence and actions of a number of different people are reviewed: metallurgy teachers, philanthropic political figures and businessmen, and individuals dedicated to raising the standing of metallurgy. Altogether it is possible to point to perhaps a dozen people who were responsible for bringing about developments which have had substantial impact upon the growth of metallurgical instruction, although not all of them took actions which were consciously aimed specifically at furthering metallurgy. Some, exemplified by Bernhard Samuelson in the nineteenth century and Lord Eustace Percy in the twentieth, were concerned with the position of national technical education as a whole: they persuaded Government to effect changes which enlarged the field of technological instruction, and in this same category came several others not considered here, such as Lyon Playfair and J.F.D. Donnelly.

By contrast a small number of others were involved directly with metallurgy. Several of these influenced public opinion, or the opinion of particular restricted groups, concerning the desirability of providing metallurgical tuition. Two academics, Professors W.C. Roberts-Austen and H.C.H. Carpenter, both of whom received knighthoods, were outstandingly well placed to make the case for metallurgy when they gave lectures to major learned societies as well as when they attended committees of the same societies and those of Government. Professor R.S. Eutton, the industrialist turned academic,

(58) THE METALLURGIST, 'An interview with Dr. J.W. Jenkin, past president (1946-8)'. Metallurgist Mats.Technologist, vol.5 (Feb.1973),79.

was another who, in the 1940s, sought the ear of Government to promote the cause of metallurgical instruction, while he also enjoyed good contacts with industry and with the wealthy Worshipful Company of Goldsmiths.

In contrast with their numerous fellow proprietors of steelworks, Andrew Carnegie and R.A. Hadfield stand out distinctively as men prepared to give generous sums of money to encourage the study of metallurgy; and Carnegie obtained his wealth by exertions in the USA, not Britain. Besides giving financial help, Hadfield was an active and eloquent communicator, making opportunities to stress the significance of the subject of metallurgy. In the industrial sphere outside iron and steel, during the last few years of the period 1851 - 1950 large benefactions to help individuals to acquire metallurgical knowledge came from Viscount Nuffield, through the Nuffield Foundation, and from the Mond Nickel Company. In the latter case the influences of two successive chief executives of the company, D. Owen Evans and Sir William T. Griffiths, were responsible for the substantial financial aid that was forthcoming. While these men were able to exert notable influence upon metallurgical instruction by persuading their fellow directors to release company funds for the purpose, Dr. J.W. Jenkin impressed his viewpoint by expending considerable time and energy over a period of many years.

The people noted were the front-line contributors to developments: it is assumed there was behind them a 'second rank' of others, here un-named, who also materially aided the growth of metallurgical instruction. It is concluded that the efforts of the small number of identifiable individuals had considerable influence.

CHAPTER 11

A LOCAL CASE STUDY : DEVELOPMENT OF FORMAL METALLURGICAL INSTRUCTION
IN THE IRON-AND-STEEL TOWN OF MIDDLESBROUGH

To give some idea of the way in which local industry, as well as other factors, might influence the development of formal metallurgical instruction, it may be instructive to consider what occurred in Middlesbrough, in north-eastern England, although it is not claimed that what happened in this town is necessarily typical. Moreover, interest in instruction in Middlesbrough stemmed from iron-and-steel production rather than from the other industrial sectors involving metallurgy such as non-ferrous production or the fabrication of metals, sectors which might be expected to require a higher proportion of skilled labour and people with metallurgical knowledge. Coincidentally, Middlesbrough's production of blast-furnace iron dates from 1851; by the early 1860s, the district had become recognised as one of the country's chief sources of both crude pig iron and refined, or malleable, iron, with a sizeable and growing immigrant population. During the 1860s the district's leading industrial figure, the ironmaster Henry W.F. Bolckow, gave nearly £6000 to help provide primary schools in the new town.

In 1861 the Middlesbrough mechanics' institute, then seventeen years old, became one of the first in the north of England to offer candidates for the

Science and Art Department's examinations in chemistry,⁽¹⁾ and more than a dozen students were involved in each of the next few years. However, in October 1867, as only one came forward for chemistry tuition, the class did not run.⁽²⁾ Also in the 1860s, there was brought into being the Cleveland Institution of Engineers, whose aims included the spread of technical knowledge by presentation and discussion of papers on subjects of metallurgical and engineering interest. While this was to remain a local learned society throughout the period ending in 1950, the Iron and Steel Institute was to be a national one: between the founding of the latter institute in 1869 and its move to a London base in 1875, its offices were in Middlesbrough.⁽³⁾

In connexion with the town's mechanics' institute, soon after 1870 'an attempt was made to form day-release classes in mathematics for local apprentices', according to one source, but it failed due to the employers' unsympathetic attitude. However, from 1871 evening mathematics classes were held with more success under the auspices of the Science and Art Department, together with ones in both mechanical and architectural drawing. In 1878 the Science and Art Department inspected and approved new chemical laboratories associated with the institute.⁽⁴⁾

Around 1870 a boys' high school for Middlesbrough was started, largely by the exertions and funds of several who were engaged in local industry. T. Hugh Bell (b.1844-d.1931), son of Isaac Lowthian Bell of the great Clarence Ironworks, took an active interest in the project from the beginning, and was to remain a champion of educational developments in the town for 60 years. The necessary land was given by the Peases of Darlington, who had extensive iron and coal interests; the Bells and Bolckow each contributed £1000 for the high school, and the Owners of the Middlesbrough Estate, consisting largely of the Pease family, undertook to build the boys' part of the school at a cost of £7000.⁽⁵⁾ Bernhard Samuelson, who was another ironmaster in the locality, contributed

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- (1) BUTTERWORTH, H., 'The development of technical education in Middlesbrough, 1844-1903'. Durham Rsch.Rev., vol.3, (Sep.1960), pt.2, 28.
- (2) POPPLE, J., 'The mechanics' institutes of the East and North Ridings of York, 1837-1887'. Vocational Aspect, vol.10, no.20 (Spring 1958), 37 fn.
- (3) LAKE, H.C., 'The next 100 years' (presidential address). Jrnl.Iron Steel Inst., vol.208 (June 1970), 525.
- (4) BUTTERWORTH, H., op.cit., 29.
- (5) LEONARD, J.W., Constantine College. (Middlesbrough: Teesside Polytechnic, 1981), 15.

£1000 towards the cost of adding a section for girls, but by 1882 he had grown impatient with what the trustees of the high school had achieved and, with the backing of other local industrialists, he agitated for what he called 'a metallurgical school' for the town.

It is difficult to know exactly what Samuelson envisaged, but in the preceding decade he had been involved with the founding of the Yorkshire College of Science in Leeds and with the establishment of the College of Physical Science in Newcastle-upon-Tyne.⁽⁶⁾ Moreover, it was just at this time that he was chairman of the Royal Commission on Technical Instruction, and he was likely to be aware of the contemporary developments in Birmingham and Sheffield. In Birmingham regular evening metallurgy classes were in course of formation in connexion with the Birmingham and Midland Institute, while in Sheffield plans were afoot for the opening of a technical school to include metallurgy. Also about this time, Samuelson agreed to sponsor a technical institute for Banbury where he had his agricultural-implement works: it was at the opening of this institute in 1884 by A.J. Mundella that Samuelson's baronetcy was announced, for services to the education of the people. In his presidential address to the Iron and Steel Institute in 1883, Bernhard Samuelson observed that 'the iron manufacturers of Westphalia have been the first to found an institution in which the intelligent and ambitious ironworker can qualify himself by study for a higher position'. He went on to express his hope that when the institute visited Middlesbrough in the autumn of the same year 'some progress will have been made in that locality towards the establishment of a similar school'.⁽⁷⁾ Unfortunately, members of the Iron and Steel Institute were to be disappointed on that score. It seems that, by their intransigence, the Middlesbrough high-school trustees may have missed an opportunity to profit from Bernhard Samuelson's munificence. In any event, in the compromise which followed the confrontation, Samuelson agreed to support the trustees' scheme to spend £6000 on building a science block for the school and to employ a science teacher.⁽⁸⁾ For their part, the Samuelson faction secured the starting of evening classes.

In the autumn of 1885 evening 'science' classes were begun at the school, immediately attracting 293 enrolments, and drawing students away from the

(6) POTTS, A., 'The educational work of Sir Bernhard Samuelson ...'.
Unpublished M.Ed. thesis, University of Durham (1969), 55-56.

(7) POTTS, A., op.cit., 96.

(8) POTTS, A., op.cit., 44-45.

mechanics' institute; by 1896 this older teaching centre had lost all its classes to the high school. In 1887 the Science and Art Department recognised part of the boys' day school as a 'science school', and offered some forty scholarships to help students to attend. Each of these Government scholarships had to be matched by similar amounts provided by local donors, who included Sir Bernhard Samuelson, T. Hugh Bell, Bolckow Vaughan & Co., and the Peases. The evening classes available included metallurgy, mechanical engineering and, in preparation for the City and Guilds' examinations, iron and steel.⁽⁹⁾ From 1886 to 1902 the teacher for the City and Guilds' classes was one of the local works' metallurgical chemists, C.H. Ridsdale, who had obtained his own training as a pupil of the Cleveland consultant chemist and metallurgist J.E. Stead.⁽¹⁰⁾ In the 1880s help with building extensions came from both local businessmen and London livery companies: local sources supplied £2300, of which £1000 came from Sir Bernhard Samuelson, while the Drapers' Company gave £550 and the City and Guilds of London £500.⁽¹¹⁾

Some figures for Middlesbrough students sitting Science and Art Department examinations in metallurgy indicate that during the last two decades of the nineteenth century the numbers fluctuated widely, Table 11.1. The decrease in

Table 11.1. Middlesbrough Science and Art Examinations in Metallurgy

Year	Subject : Metallurgy Theory			Subject : Metallurgy Practical		
	National total sitting exams.	M'bro'. students attending classes	M'bro'. students as proportion of nat. total	National total sitting exams.	M'bro'. students attending classes	M'bro'. students as proportion of nat. total
1880	277	0	0 %	0	0	0 %
1885	351	30	8.5 %	126	20	16 %
1890	514	10	2 %	253	10	4 %
1895	534	0	0 %	391	0	0 %
1900	463	0	0 %	370	0	0 %

Based on MUSGRAVE, P.W., 'Metallurgy and the Department of Science and Art, 1870-1900'. In MUSGRAVE, P.W., (ed.) Sociology, history and education a reader, (London: Methuen, 1970), 268, 270.

(9) BUTTERWORTH, H., op.cit., 30.

(10) Iron Coal Tr.Rev., vol.82 (12 May 1911), 771.

(11) POTTS, A., op.cit., 45-46.

Middlesbrough numbers after 1885 may be accounted for by the starting of tuition for the alternative City and Guilds' examinations in iron and steel. This explanation is supported by the fact that no similar drop during the years in question is shown by the corresponding figures relating to mathematics and chemistry.

During the 1890s the high school received a certain amount of aid from Middlesbrough council, but only a minor fraction of what could have been provided had the town made full use of the provisions of the Technical Instruction Act of 1889 and the Local Taxation (Customs and Excise) Act of 1890. Thus, between 1891 and 1895 the council gave the school £1486 out of the £5204 received under the 1890 Act, ⁽¹²⁾ and in the twelve years from 1890 to 1903 a total of £6066 was paid by the council to the school. It has been estimated that if the penny rate allowed by the 1889 Act had been levied, and if the full amount of money accruing to the council under the 1890 Act had been paid, another £20 000 would have been available for technical education. ⁽¹³⁾ As it was, in the later years of the 1890s the working of the boys' school resulted in financial losses, and in 1900 the high school's trustees handed over their charge to the Middlesbrough county borough council.

The lack of money in the latter part of the nineteenth century prompted the remark attributed to an HM Inspector in 1901 that Middlesbrough was 'far behind any other town for its size in the district in its provision of technical instruction'. ⁽¹⁴⁾ With the meagre finances on which the high school had had to exist it is not surprising a report in 1903 indicated that 'the metallurgy department of the high school was hopelessly inadequate ... and the building construction and engineering departments were just as bad', with 'no appliances for ... teaching ... practical iron and steel metallurgy ... (and) no means of chemically analysing iron and steel or mechanically testing products'. ⁽¹⁵⁾ This account has to be weighed against one of the situation ten years before, when a 'specially equipped metallurgical laboratory' existed, but as only ten candidates

(12) DRURY, J.H., 'The history of education in Middlesbrough ...'. Unpublished M.Ed. thesis, Victoria Univ. of Manchester, (1940), 60.

(13) BUTTERWORTH, H., op.cit., 33; LEONARD, J.W., op.cit., gives details, Table 4, 170.

(14) MUSGRAVE, P.W., 'Metallurgy and the Department of Science and Art, 1870-1900'. In MUSGRAVE, P.W. (ed.), Sociology, history and education a reader, (London: Methuen, 1970), 269.

(15) DRURY, J.H., op.cit., 62.

were taught for the practical metallurgy paper of the Science and Art Department the space was used for school physics.⁽¹⁶⁾ However, inspectors' reports made in 1906 and 1907 repeated the criticism of the lack of both accommodation and equipment; in 1913 the report observed that the staff were doing good work in the prevailing 'very adverse conditions'; and in 1914 the report commented that there 'was not sufficient equipment for teaching metallurgy (and) no appliances whatever for teaching practical iron and steel metallurgy'.⁽¹⁷⁾ These comments were made about the facilities existing in the high school which had set itself out to provide the most-advanced technical instruction in an important iron-and-steel district.

Despite the adverse circumstances, five-hundred students attended day and evening classes in the early 1900s, lack of accommodation preventing any marked increase in numbers from occurring during the first three decades of the present century. Soon after the new century had opened, one of the district's leading iron-and-steel companies, Dorman Long & Co. Ltd., became exceptional in making arrangements for apprentices to spend one afternoon a week at technical classes at the high school during working hours.⁽¹⁸⁾ By the arrangement thirty-five students aged sixteen and upwards attended the first of such 'engineering' classes in 1902. A few years later two Sheffield companies, Vickers Sons and Maxim Ltd. and Samuel Osborne, were promoting similar 'day-release' schemes, while at Woolwich the Royal Arsenal working under direct Government control sent 'trade lads' to the local polytechnic. These day-release arrangements entailed attendance at evening classes too, as did the many other instances where academic instruction during the working day was looked on with disfavour. The Teesside engineers and iron founders, Head Wrightson & Co., whose activities were closely linked with the iron-and-steel industry, introduced compulsory evening classes for apprentice fitters and turners shortly before 1900. Soon afterwards an engineering company in nearby Hartlepool, Richardsons Westgarth & Co. Ltd., introduced a modification to its training scheme whereby each apprentice, 'on reaching a certain standard for timekeeping, perseverance, ability, and good conduct in the shops, and for passing examinations at the

(16) MUSGRAVE, P.W., loc.cit.

(17) LEONARD, J.W., op.cit., 18-19.

(18) MUSGRAVE, P.W., Technical change the labour force and education ... 1860-1964. (Oxford, etc.: Pergamon Press, 1967), 89 and 92; quoting SADLER, M.E., Continuation schools in England and elsewhere, (Manchester, 1908), 278-9 and 290-91.

evening classes, obtained an increase in his weekly pay for the whole year.'⁽¹⁹⁾ Among the reasons advanced for the general reluctance of employers to release young apprentices for formal tuition during the working day was the fact that many of them were being used as cheap labour, doing men's work but not receiving the recognised wages for it, and they could not well be spared. A commentator in the late 1930s observed that this was commonplace in the heavy industries of his day.⁽²⁰⁾

The formal classes in which local engineering employers were interested would be in subjects such as mechanics, mathematics, and engineering drawing, and not specifically for metallurgy. Any local people who aspired to advanced studies of any kind had to go elsewhere for them. As far as metallurgy was concerned, Sheffield and Newcastle were the nearest centres, but Newcastle offered only full-time day courses and Sheffield with its arduous part-time Associateship course was completely out of reach for daily travel. After about 1910 the University of Leeds offered courses in fuels and metallurgy, but again, attendance at these would hardly be practicable for anyone with a job in Cleveland. London external-degree examinations following private study were an alternative which an exceptional and select few attempted. Harold Moore, a Middlesbrough boy who was to become in the 1940s one of the founders of the Institution of Metallurgists and its first president, was successful in obtaining the London B.Sc. degree in science in 1898 at the end of three years' unremitting private evening study combined with his strenuous working days as a pupil in J.E. Stead's analytical laboratory.⁽²¹⁾

Technical colleges for formal instruction were opened in some north-eastern industrial towns before 1910: at both Darlington and West Hartlepool in 1897,⁽²²⁾ and in Sunderland in 1901. By contrast, Middlesbrough had none. Largely through the determination of Sir Hugh Bell a plot of land was obtained for the town, and some years later in 1913 alternative schemes costing £7000 and £25 000 were drawn up for a technical college and art school. It was envisaged that,

(19) ANON., 'The training of apprentices'. Page's Weekly, vol.6 (20 Jan.1905), 116.

(20) DRURY, J.H., op.cit., 115.

(21) MOORE Harold, 'Some recollections'.
The Metallurgist, vol.1, no.1 (1960), 30.

(22) PATTENDEN, D.W. (ed.), From telegraphs to nuclear power.
(Middlesbrough: Instn.Electrical Engrs., Tees-side sub-centre, 1969), 71-72.

in the more-costly scheme, besides advanced instruction in plumbing, engineering, woodwork and commercial subjects, provision might be included for metallurgy.⁽²³⁾ The Board of Education was asked for money so that the proposed technical college and art school might materialise.

The Great War then intervened: on the one hand it gave the town councillors and the officials of the Board of Education an excuse for further delays, and on the other it provided a welcome upturn in industrial activity. For many years the chemical and metallurgical consultant J.E. Stead had been a staunch advocate of better technical instruction; at the time of the Great War he and the president of the Cleveland Institution of Engineers, Mr. W. Hawdon, who worked for Sir B. Samuelson & Co., were actively campaigning to establish a local metallurgical 'research laboratory'. The proposed laboratory, which would include a lecture room, was intended to promote technological understanding and improvement in the steel industry, and also to supply conditions in which those engaged in it could meet socially, perhaps borrowing something from the London 'polytechnic' idea. Stead had enlisted the support of Andrew Carnegie for the project, but Carnegie's death occurred before any definite financial help had been secured from that direction. The Cleveland Institution of Engineers supported Stead's idea, and solicited aid from local industry. As the result, promises, but not hard cash, to the extent of £36 000 were forthcoming. Dorman Long, through Sir Hugh Bell, and Bolckow Vaughan, each agreed to give £10 000. Dr. Stead himself pledged £500.

However, despite the extensive iron-and-steel and engineering industries in the Middlesbrough district, the major financial gifts which made realisation of a technical college possible came not from the industry directly, nor from the town which had grown very largely as the result of it during the previous 70 years, but from members of a ship-owning family who felt themselves to have been identified commercially with Middlesbrough. In 1916 the mayor of Middlesbrough was able to announce that Mr. Joseph Constantine, JP, was prepared to give £40 000 towards erection of a technical college. In connexion with this offer Joseph Constantine said ⁽²⁴⁾

(23) ANON., 'Technical education in Middlesbrough'. In brochure published for the official opening of the Constantine Technical College by the Prince of Wales, 1930. (Middlesbrough Central Ref. Library).

(24) ANON., 'Technical education in Middlesbrough', loc.cit.

'... when the time of peace comes we must be properly equipped to stand up against very serious competition from other countries, including Germany. To accomplish this we must get well equipped for technical instruction ...'

In the event, because of delays and rising prices during the 1920s, altogether the Constantine family came to contribute £80 000 for the technical college building. The primary object of the proposed college, as it was seen before 1920, was to be⁽²⁵⁾

'the encouragement and advancement of technical knowledge and research in ...

(i) metallurgy;

(ii) engineering, including its application to iron and steel works, shipbuilding and mining;

(iii) chemistry and its application to metallurgy and engineering, and more particularly to coal, coke and their by-products;

(iv) such other branches of the pure and applied sciences as may be necessary in connection therewith. '

Dr. Stead's proposal was thus the catalyst by which substantial funds for the promotion of technical instruction came to the Middlesbrough council through the generosity of individuals. Even so, the scheme was not realised for another thirteen years. Part of this delay could be attributed to objections raised by the Board of Education regarding features of what was proposed; by about 1920 these had been resolved, but it was not until 1927 that building work commenced. The new Constantine Technical College came into use for classes in September 1929.

In 1919, before the scheme for a technical college materialised, a 'junior technical school' was started in the town to provide selected thirteen-year-olds with a three-year course of general education which would fit them for entry to certain sections of local industry, for example as apprentice draughtsmen, craft apprentices, and for work in the metallurgical laboratories.⁽²⁶⁾ This technical school remained into the 1950s a major source of recruits for skilled

(25) ANON., loc.cit.

(26) LEDGARD, A.T., personal communication, 1978.

Mr. A.T. Ledgard was a pupil at the school in the early 1930s and went on to become a senior manager in the local iron-and-steel industry.

work in the local industries. A source of general discontent with such schools was the fact that whereas the grammar-school pupils were selected at the age of eleven, students for the technical schools were commonly not chosen until they were two years older, so that inevitably the grammar schools had first pick. In Middlesbrough the age of entry to the technical school was to be lowered in 1953 to eleven years, entailing a five-year course in place of the three-year one.⁽²⁷⁾

In the early 1920s when the governing council for the new Constantine College was first convened, local employers in the iron-and-steel industry were well represented. Soon after this there was mention that 'at least one large concern' in the district was running 'its own classes in mechanical and constructional engineering, metallurgy and metallography',⁽²⁸⁾ but further information relating to the efforts of industrialists at that period is not readily available. The continued trade depression and the lack of facilities at the high school were probably jointly responsible for the report in 1928 that the metallurgy course offered there was 'of low standard and maintained only with difficulty'.⁽²⁹⁾

Five local sources connected with the iron industry in 1916 made payments towards equipping the proposed college, that from Sir B. Samuelson & Co.Ltd. heading the list at £5000. By the time the new college was built, close to £20 000 had been raised by subscriptions. Of the total equipment costs of £33 000, the 'department of metallurgy and pure science' took £9750, while that of engineering accounted for £10 800. At the college's official opening, some twenty years after such a development had first been seriously mooted, it was gloomily reported that⁽³⁰⁾

'unfortunately several of the firms who promised large subscriptions but have not paid them have intimated that owing to the depression in trade they are not able at present to carry out their promises'.

(27) LILLIE, William, The history of Middlesbrough
(Middlesbrough: County Borough Council, 1968), 446.

(28) LEONARD, J.W., op.cit., 46.

(29) DRURY, J.H., op.cit., 110-111; quoting from Middlesbrough Education Committee minutes of 1927-28 recording W. Edward's report of 1 Mar. 1928.

(30) ANON., loc.cit.

Conspicuous among the defaulters was the long-established company of Bolckow Vaughan. In the 1850s and 1860s this had been recognised as the foremost member of the great Cleveland iron trade, and around 1880 it had pioneered the production of 'basic' steel. However, as a result of financial difficulties in the 1920s it was forced by its bankers into a merger in 1929 with its former chief rival, Dorman Long & Co.

In September 1929 when the new college building opened, more than 1200 students were enrolled for classes, the overwhelming preponderance being for evening studies only. Ten years later there were 2300 students attending, while after the war years of 1939-45 the numbers rose further, to exceed 4000 in 1950. A major problem for the college during the first two decades of its existence was the paucity of day-time students. For instance in 1930-31 the proportion of day- and part-time students was only 7.3 per cent, or 1 in 14 of the total; by the late 1940s this proportion had risen to more than one third.⁽³¹⁾

In drawing up plans for the proposed technical college in 1924 the director of education in Middlesbrough determined that its most important sectors should be metallurgy and mechanical engineering and that, following from this, the principal should be 'well qualified in metallurgical science' while the next member of staff in order of seniority should be the head of mechanical engineering. The college's first principal was Dr. D.H. Ingall, D.Sc., who came to Middlesbrough in 1928 from Wednesbury County Technical College where he had been principal and head of the metallurgy department and had held office as president of the Staffordshire Iron and Steel Institute. For the post, which carried a salary of £900 rising to £1200, there were 47 applicants, a short list of five names being submitted for comments to three established academic metallurgists, Professors C.H. Desch of Sheffield, C.A. Edwards in Swansea, and H.C.H. Carpenter of the Royal School of Mines in London. Soon afterwards a 'head of metallurgy', Mr. C. Groves, was appointed at £500-£600; he came from a lectureship at Bradford Technical College.⁽³²⁾ However, after little more than two years in Middlesbrough, Dr. Ingall left for other work as assistant director and research manager of the British Non-Ferrous Metals Research Association;⁽³³⁾ a year or two later again, he became principal of the

(31) LEONARD, J.W., op.cit., 185.

(32) LEONARD, J.W., op.cit., 50.

(33) Mining Magazine (London), vol.43 (Sep.1930), 130.

Borough Polytechnic in South London. In 1931 a new principal for the Constantine Technical College began work: like his predecessor, Dr. T.J. Murray possessed experience in metallurgy and he came to Middlesbrough from a college principalship in the Midlands, this time the Smethwick Municipal College.⁽³⁴⁾ He also was faced with difficulties of financial stringency, an unbalanced attendance schedule between day and evening work, and insufficient student enrolments in some subjects for classes to be run.

Whatever the reasons for the first principal's rapid move away from Middlesbrough, there is no doubt that the opening of the Constantine Technical College was hailed by the Board of Education as one of the greatest contemporary national achievements in the field of technical instruction. Surveying the facilities available for such instruction in metallurgy, a Board of Education report published in 1931 noted that⁽³⁵⁾

'the most complete provision of modern accommodation and equipment is at Middlesbrough and Wednesbury. Both these schools possess specially designed and well-equipped laboratories for the study of modern metallurgical processes and problems.'

The report also found that, for the metallurgical areas of Yorkshire and Lincolnshire, 'opportunities for work of the highest standard' were provided at two places, the applied science department of the University of Sheffield and the Constantine Technical College in Middlesbrough. Lincolnshire ironmasters, incidentally, were willing to offer a scholarship of £100 tenable at Sheffield.⁽³⁶⁾

In spite of the well-equipped metallurgical laboratories, there is no evidence of any great upsurge of students anxious to take advantage of them. Closely following similar courses in Sheffield and Scotland, in 1931 practical classes for operatives 'were organised in iron and steel, and in rolling'.⁽³⁷⁾ An operatives' course in foundrywork was supplemented by practical experience in foundries 'placed at the disposal of the college by interested employers'.⁽³⁸⁾

(34) LEONARD, J.W., op.cit., 57.

(35) BOARD OF EDUCATION, Report of H.M. Inspectors on the provision of instruction in applied chemistry in technical schools and colleges in England and Wales. (HMSO, 1931), 20, 22-23. (Board of Education, educational pamphlets, no.35).

(36) BOARD OF EDUCATION, loc.cit.

(37) MUSGRAVE, P.W., Technical change ..., op.cit., 160-161.

(38) BOARD OF EDUCATION, op.cit., 25.

One of the chief foundries in the district was Cochrane's, and in 1916 A.O. Cochrane had been a subscriber of £500 to the funds for development of local technical instruction. A two-year full-time course in foundry technology was started in 1930 as the first of its kind in the country,⁽³⁹⁾ but it seems to have been an early casualty. Soon a committee of the college's governing council agreed that steps should be taken to make the course known nationally, and a year or two later the principal promised that efforts would be made to revive the class. Later in the 1930s, however, in two successive years individual students at the college were awarded silver medals presented by the Institute of British Foundrymen, and on one occasion a student gained first place nationally in the City and Guilds' patternmaking examinations.⁽⁴⁰⁾

A proposal of the early 1930s was that an approach should be made to the University of Durham to recognise the metallurgy courses in Middlesbrough for the award of its degrees, but nothing came of it; such an arrangement would have been similar to ones made between the university and the Sunderland Technical College. On the other hand, representatives of the University of London visited the Constantine Technical College and gave approval for training students for degrees in engineering, chemistry, and metallurgy.⁽⁴¹⁾ Thus the college Prospectus for 1933-34 was able to advertise full-time courses in preparation for the London B.Sc. degree in metallurgy. Over the years, it was the occasional strongly-motivated individual who took advantage of the tuition offered for this goal. As far as the classes leading to the City and Guilds' qualifications in the subject were concerned, in at least one year, 1937, there were no entries from Middlesbrough: nationally there were only 110 candidates, of whom two came from Newcastle and three from Consett.⁽⁴²⁾ During the 1930s the principal was a member of the City and Guilds' general advisory council for metallurgical subjects, while in 1945 the head of the college's metallurgy and science department took part in discussions with the same body. Throughout negotiations in the 1940s for the introduction of national certificate schemes in metallurgy, the principal represented the Northern Counties Technical Examinations Council.⁽⁴³⁾

(39) DRURY, J.H., op.cit., 113 fn; quoting Special Supplement to the Tees-side Chamber of Commerce Monthly Jnl., (July 1930), 13.

(40) LEONARD, J.W., op.cit., 56; 58; 65.

(41) LEONARD, J.W., loc.cit.

(42) DUNNING, J., op.cit., 23.

(43) DUNNING, J., op.cit., 3; 167-8; 58.

For students of engineering, in Middlesbrough in 1938 day-time courses for both ordinary and higher national diplomas were started, and it was said that two firms, Dorman Long and Smith's Dock Co., afforded generous support for them. These were three-year sandwich courses, Dorman Long being prepared to release up to eight apprentices each year on full wages to study for six months. By 1947 the sandwich courses in engineering offered at the Constantine Technical College were being supported by ten companies, among them two more in the iron-and-steel industry, the Cargo Fleet Iron Co. Ltd. and the Skinningrove Iron Co. Ltd.⁽⁴⁴⁾ For metallurgy, alas, there was nothing comparable, for the corresponding national certificates and diplomas did not come into being until the last five years before 1950. It seems likely that, in the Middlesbrough district, many who could have studied metallurgy appropriately were obliged to turn instead to either engineering or chemistry because the opportunities for courses in these subjects were greater. Thus, by its inability to offer nationally-recognised courses other than those leading to the City and Guilds' qualifications, the technical college's department of 'metallurgy and science' was bound to lose ground in metallurgy relative to other subjects. There were, it is true, metallurgical 'endorsements' available for higher-national certificates in engineering, but these were begging the question.

In some other parts of Britain the first ordinary-national certificates (ONCs) in metallurgy, based on part-time and evening study, were awarded in 1946; in Cleveland, however, the first final ONC examinations were held only in 1949, when a single candidate was successful, compared with the national total of 107. In the years between 1950 and 1954, Middlesbrough produced an average of six ONCs a year compared with 181 nationally, or 3.3 per cent. of the total. The corresponding examinations for the higher-national certificate (HNC) in metallurgy first took place locally in 1948 when six students were successful out of the country-wide figure of twenty-two, but in the five years from 1950 to 1954 the local numbers averaged only two-and-a-half a year out of the national total of 95, equivalent to 2.5 per cent.⁽⁴⁵⁾

During the more affluent years of the 1960s it was to prove possible at the Constantine College to run full-time diploma courses in metallurgy, and the national

(44) LEONARD, J.W., op.cit., 62; 65; 76.

(45) DUNNING, J., op.cit., 110; 213.

college governors were to approve the establishment of a separate department devoted to the subject. For several years the chairman of the governors was to be the general manager of the local steel company Dorman Long. As a result of the policy of the local education authority there was also to come about a system whereby, together with that in other subjects, formal metallurgical instruction at the lower levels was to be made available in a number of 'feeder' technical colleges in the district. In the same period of optimistic expansion, around 1960 Middlesbrough's junior technical school was to be discontinued, with some elements from it incorporated in a new Brackenhoe county secondary school for boys situated on the southern outskirts of the town.⁽⁴⁶⁾

In the two decades immediately before 1950 during which the Constantine Technical College was open as the district's centre for technical instruction, the discipline of 'metallurgy' within the college was bracketed in a single department with 'science'. In view of the relatively small numbers of students gaining metallurgical qualifications, such a joint approach would seem to have been justified.

There appears to be little doubt that the development of facilities for formal technical instruction in the district was impeded, over the years, by the divided loyalties of the various communities affected by it. Besides the county borough of Middlesbrough itself, lying north of the river within County Durham was the neighbouring town of Stockton, and on the southern side close to Middlesbrough, parts of Cleveland such as Eston, South Bank and Redcar, which were contained within the North Riding of Yorkshire. It is suggested this split allegiance, with the mutual jealousies it generated, was a major factor which hampered progress in local technical education as a whole.

Middlesbrough has been commonly cited as an example of a town which came into existence in Victorian times. In 1851 the population was just under 8000; twenty years later it had grown to 40 000, and at the opening of the twentieth

(46) LILLIE, W., loc.cit.

century it was 100 000. In 1950 Middlesbrough's population was nearly 150 000, while the district for which the Constantine College served as the major source of formal technical instruction contained some 300 000 people.⁽⁴⁷⁾ These figures are small by comparison with Newcastle-upon-Tyne's 300 000 for the city alone, Sheffield's and Leeds's half a million each, and Birmingham's population of more than one million. Middlesbrough's small size was another factor which mitigated against the development of facilities for technical instruction.

However, from 1850 the town and its surroundings possessed metallurgical industry, and in subsequent decades this industry was on large scale and of considerable national importance in terms of outputs of iron and steel. In the district during the first half of the present century there was also a growing chemical industry. In view of this extensive metallurgical activity the small demand for classes in metallurgy points to the conclusion that those in positions of responsibility in the local industry were not greatly interested in formal metallurgical tuition and certain did not value it highly.

(47) NORTE, G.A., Teesside's economic heritage.

(Middlesbrough: Cleveland County Council, 1975), 150; 153; 171.

CHAPTER 12A COMBINATION OF ECONOMIC AND SOCIAL FACTORS

This thesis is concerned with the century 1851 - 1950. At the opening of the period 'metallurgy' was already well established as a branch of technology. According to the Oxford English Dictionary, in 1704 metallurgy was described in a textbook as 'The working or operation upon metals, in order to render them most fine, hard, bright, beautiful, serviceable, or useful to mankind'.⁽¹⁾ However, in 1861 a somewhat different definition was published: 'the art of extracting metals from their ores and adapting them to various purposes of manufacture'.⁽²⁾ This nineteenth-century view of the subject was the one which predominated in British metallurgical instruction until 1901, after which there occurred a gradual shift back towards concordance with the eighteenth-century definition. In any event, in 1851 it could be stated, with truth, that 'in Great Britain the practice of metallurgy has attained an unparalleled degree of development ... (despite) the absence of public instruction in (it)'.⁽³⁾

In the decades following 1851 the scale on which metallurgy was practised grew exponentially as greater quantities of metals with an ever-widening range of characteristics were brought into use to improve the material well being of mankind. Throughout the hundred years, the extraction of metals from their ores and the provision of metallic objects possessing properties suited to their purpose was thus a fundamental activity in furthering

(1) JENKIN, J.W., 'A metallurgist has a few words'. Metallurgist Materials Technologist, vol.7 (Jan.1975), 43.

(2) PERCY, John, Metallurgy ... fuel, fire-clays, copper (London: John Murray, 1861), 1.

(3) PERCY, John, 'On the importance of special scientific knowledge to the practical metallurgist ...'. Records School of Mines (Geol.Survey Great Britain), vol.1 (1852), 137.

'civilisation' as it was understood by 'the west'. A substantial share of the world's metallurgical work was done either within Britain or in the British Empire. As far as the production of non-ferrous metals such as copper, zinc and gold was concerned, by the year 1901 deposits in overseas territories had acquired greater importance than those at home, although financial control of much of the exploitation rested in London.

The growing demand for metallic materials capable of fulfilling new functions, coupled with the application to metal processing of novel techniques such as electrolysis and extrusion, led to considerable expansion in the breadth of knowledge that was available on the subject. Particularly during the second half of the period under consideration, that is from 1901 to 1950, researches revealed the detailed properties and structures of a wide variety of alloys, and brought understanding of the fundamental causes of the phenomena. Such observations, allied with postulations made to explain the observations, were being vigorously pursued when the period ended in 1950.

On the face of it, 'metallurgy' would appear to have been strategically placed during the whole hundred years, closely associated with technological progress involving mechanical, electrical, and structural engineering. Metallurgical instruction likewise might be expected to have shown striking development and to have commanded a key position in technological education. The reality, however, was very different, with metallurgy classes treated as the poor relation and offshoot of those in other disciplines, notably chemistry and mechanical engineering. An interesting and basic question, then, is why metallurgical instruction fared comparatively badly for at least four fifths of the hundred years? It is true that the opportunities available for formal instruction in the subject increased as the century progressed, but they did so to nothing like the same extent as in other subjects. University departments of

chemistry and engineering proliferated much more than those in metallurgy; national certificate schemes in the two former subjects were offered soon after 1920 whereas that for metallurgy did not materialise until a quarter of a century later. There appear to have been many causes contributing to this relatively poor performance of metallurgical instruction.

The motive for the 1851 opening of the Government School of Mines in London with its significant metallurgy section was the desire of some influential people to improve the economic position of Britain and the Empire. The harnessing of natural resources through the media of agriculture and mining with metallurgy was seen as fundamental to achieving the desired improvements.

'Schools of mines' were considered suitable practical vehicles by which encouragement might be given to appropriate technologies. The London school had as its predecessors institutions established more than fifty years earlier in Paris, at Schemnitz in Hungary, Freiburg in Saxony, and St.Petersburg in Russia. The fashion for schools of mines was to be continued, for instance in the USA, with the starting of Columbia College School of Mines in New York in 1864,⁽⁴⁾ the Missouri School of Mines situated in Rolla a few years later, and the New Mexico School of Mines at Socorro in 1889. In the USA, State-sponsored agricultural and mining colleges were a feature of the last four decades of the nineteenth century, and by 1893 a dozen institutions offered instruction in metallurgy.⁽⁵⁾ In the British Empire schools of mines were founded in Australia, at Ballarat in 1871 and at Bendigo two years later,⁽⁶⁾ in New Zealand at Otago University in 1879, and in South Africa around the turn of the century.⁽⁷⁾

(4) BOSHKOV, Stefan, 'Mineral industry education in the United States. Henry Krumb School of Mines'. Mining Congress Jrnl., vol.64, no.11 (Nov.1978), 43.

(5) ANON., 'Mining schools of the United States'. In ROTHWELL, R.P.(ed.), The mineral industry its statistics technology and trade for 1893, vol.2 of annual series, (New York: Scientific Publ.Co., 1894), 820-821.

(6) WORNER, Howard K., 'Metallurgy in Australia'. The Metallurgist, vol.1, no.1 (Jan.1960), 42.

(7) WILSON, A.J., 'The "dreaming spires" of mining'. Optima, vol.30, no.1 (July 1981), 37-53.

Within Britain, the civic universities that came into being in the years around the end of the nineteenth century were aware of the established pattern and, at any rate in some instances, followed it. The University of Birmingham, chartered in 1900, included departments of metallurgy and mining influenced by North-American practice, the newly-appointed professors of the two subjects being sent on fact-finding tours of academic departments in the USA; already there was fifteen years' experience of teaching metallurgy at two centres in the city, Mason's College and the Birmingham and Midland Institute.

There was, then, during the nineteenth century a tradition for the inclusion of metallurgy in any teaching institution set up to promote industries based upon mining and agriculture. This might be deemed a favourable influence, but in practice a number of circumstances affected the outcome adversely. In the first place, a fundamental requirement for successful metallurgical instruction was a supply of students, and this was not necessarily forthcoming. Secondly, the existence of informed metallurgical activity within the institution or its neighbourhood was desirable. In Sheffield, for instance, such activity was present, as it was in the Birmingham area, but close to some other academic centres it was less strongly pursued industrially while within the institutions themselves the flame was weak.

Moreover, while it was likely that metallurgical activity would exist near metalliferous mines, such as those of the Erzgebirge of Europe or the State of Missouri in the USA, it did not follow that metallurgists would be found in association with coal mines, although it is true that British iron smelters were located near coal deposits and in South Wales coal made Swansea a leading metallurgical town.

Another factor handicapping British institutions which tried to emulate the Continental model of mining schools was that whereas in the latter, because the related mineral industries were State run, students were readily admitted to smelting works to gain first-hand practical experience, in this country

the position was totally different so that students experienced difficulty and hostility. Metallurgical tuition conducted in a mining school, with its close relationship with mining, was not always the most appropriate arrangement for promoting those portions of the subject intimately bound up with engineering, such as the mechanical properties and behaviour of various alloys. Altogether, for several reasons the 'school of mines' model was not necessarily well suited to the circumstances prevailing in Britain at any time after 1851.

The wealth of the country was derived from manufacturing trade goods of all kinds rather than from producing bulk metals, and greater investment in instruction aimed at fostering such manufactures would have been likely to pay national dividends. An attempt in this direction had been made with the schools of design started at Government expense under the initiative of the Committee of Trade in the years around 1840, and in the early 1850s in Newcastle-upon-Tyne a plan was published for a great 'mining and manufacturing college' to be based in the town, but little came of these endeavours. The many supporters of Free Trade regarded with abhorrence the idea that public funds should be used to subsidise individual manufacturers by contributing to the trade training of employees. Consequently all technical instruction provided at public expense had to be careful to emphasise general principles and the 'scientific' bases of processes and to avoid being too specific on certain points of detail. It was this awareness of the need to design courses that would be least likely to cause political offence which resulted in critical charges being levelled at the Science and Art Department that its instruction was too theoretical and academic, too divorced from reality. However, perusal of the 1886 metallurgy syllabuses, especially the one for practical metallurgy,⁽⁸⁾ conveys the impression that, on paper at least, they provided a comprehensive and valuable insight into metallurgy; the same syllabuses would still have been appropriate

(8) SCIENCE AND ART DEPARTMENT, Prospectus of Sir Joseph Whitworth's scholarships ... Regulations ... with syllabus of subjects. (HMSO, 1886), 59-72.

in 1950, although at this later date supplementation would have been necessary to take account of the substantial advances in knowledge made during the first half of the present century. In practice, difficulty may have been experienced in obtaining adequate teaching and facilities to translate the printed syllabuses into a useful and comprehensible course of instruction.

Besides the Government's Science and Art Department, the local mechanics' institutes and literary and philosophical societies were likewise chary of supporting trade instruction, and it was left to other agencies, especially the City and Guilds of London Institute after 1880, to supply a system of encouragement more within the grasp of ordinary industrial employees. City and Guilds' classes and examinations in aspects of metallurgy were available from the 1880s, but the numbers participating were not large, and from the 1920s the courses suffered active discouragement from the Board of Education which sought to drive local authorities to provide alternative equivalent technical tuition. Particularly during the nineteenth century, but continuing to some extent until at least the 1930s, apprenticeship and pupillage were important means by which technological training might be obtained; unlike the methods of formal tuition, these were thoroughly acceptable to industrial employers. During the second half of the nineteenth century and extending through much of the first half of the present century, instruction concerned with 'manufacturing' in general seems to have received markedly less support than that for certain other branches of endeavour such as mining, civil engineering, and the traditional professions.

A circumstance which in the long term acted against the operation of viable metallurgy classes in certain districts was the close association between 'metallurgy' and 'chemistry'. There were several causes for this close relationship, which in 1851 could be fairly justified by the preponderance of chemical

features in what was then known as 'metallurgy'. In the second half of the preceding century Dr. Richard Watson, the chemistry professor at Cambridge, had contributed to lead and zinc smelting, and lectures on metallurgy had been included in the courses of several of his successors as well as in those of chemistry professors in the Scottish universities. In the early part of the nineteenth century chemistry lecturers at medical schools and other academic institutions commonly embraced 'metallurgy' within their fields of expertise. When, in 1851, the Government School of Mines opened in London, the man appointed 'lecturer on metallurgy' was Dr. John Percy, who had trained in medicine, and it is likely his training included some chemistry: almost certainly it contained more chemistry than mechanics and engineering. Thus, at the School of Mines, 'metallurgy' was largely an extension of aspects of chemistry, and metallurgical instruction was seen as similar to that in chemistry, but requiring somewhat more equipment in the laboratory, in particular a furnace.

Percy's view of metallurgy, and he was undoubtedly an ardent proponent of the subject, was spread in two ways: by past students of the School of Mines; and through the Science and Art Department's national classes and examinations, which from 1862 offered a course and qualifying examination in 'theoretical metallurgy'. By the time a practical syllabus was offered as well, in 1882, Percy had retired. In due time several of Percy's disciples became, in their turn, academic teachers of metallurgy: A.K. Huntington at King's College London, and W.H. Greenwood at Sheffield Technical School; while two of them, W.C. Roberts-Austen and William Gowland, were to succeed Percy at the Royal School of Mines. Greenwood, Roberts-Austen and Gowland all had acquired considerable industrial experience of metallurgy before they took up academic positions. It is intriguing to speculate what difference there might have been

in the standing and quantity of metallurgy classes during the present century had a different man been appointed to the post of lecturer on metallurgy at the School of Mines in 1851, a person with an outlook biased towards engineering: we can never know. What is certain is that the Science and Art Department's nation-wide syllabuses in metallurgy reflected the School of Mines' view. During the 1880s appreciable changes to the syllabuses took place, presumably at the instigation of Roberts-Austen. Before then the numbers attempting the examinations in theoretical metallurgy were relatively small, rarely exceeding three hundred a year.⁽⁹⁾

One of the difficulties in providing adequate instruction in any technological, or 'applied' subject such as metallurgy was, as indeed it remains, the fact that a major proportion of commercial operations involving the technology were performed on a large scale, and often only at a considerable distance from the teaching site. There were several ways in which the disadvantages arising from this circumstance could be mitigated, but all added to the expense of supplying tuition; they underline the fact that satisfactory metallurgical instruction was comparatively costly and required considerable facilities. For instance, in the 1880s, during the first ten years that W.C.Roberts-Austen was professor of metallurgy at the Royal School of Mines, the amount of equipment available at the school for demonstrating things such as the mechanical treatment and properties of metals was totally inadequate. The same was true in Sheffield when J.O.Arnold was appointed professor of metallurgy at the Technical School in 1889. These two schools in London and Sheffield were the chief centres at the time, and elsewhere the instructional equipment available was commonly very poor so that evening-class students entering for the metallurgy examinations of the

(9) MUSGRAVE, P.W., 'Metallurgy and the Department of Science and Art, 1870-1900'. In MUSGRAVE, P.W.(ed.), Sociology, history and education a reader, (London: Methuen, 1970), 266.

Science and Art Department or the City and Guilds' Institute were likely to be handicapped. For instance, in the iron-and-steel town of Middlesbrough successive HMI's reports during the first three decades of the present century made adverse comments about the lack of equipment. The difficulty of providing suitable equipment was recognised, and in the nineteenth century the Science and Art Department offered to supply local teaching centres with drawings of furnaces which it claimed could be simply built and would be found serviceable.

The various shortcomings in academic tuition were acknowledged throughout the period 1851 - 1950, and various steps were taken to overcome their effects. For instance, the students undergoing instruction might be taken on works' visits as part of the course. This idea was put into practice by Percy with the advanced class of artillery officers at Woolwich in the 1870s and extended by him to the Royal School of Mines' course. Percy's successor, Roberts-Austen, in his introductory lecture for the session 1880-81, said that he hoped it would be possible to arrange for such systematic visits. He observed that he had 'already received courteous promises of aid from several owners, and the wide distribution of our own men throughout the country will doubtless help to render this easy.'⁽¹⁰⁾ Again, students might be required to spend some time in works in order to gain experience, as was the custom in the Continental mining schools. At the Royal School of Mines in the 1920s students were 'strongly advised to spend the long vacation in gaining experience in metallurgical works',⁽¹¹⁾ and later a total of twelve weeks of such experience was needed to qualify for the Associateship.

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- (10) ROBERTS-AUSTEN, W.C., 'Metallurgy in its relations to chemical science' (introductory lecture to metallurgy course, Royal School of Mines, 1880-81). In SMITH, S.W., Roberts-Austen, a record of his work, (London: Griffin, 1914), 90.
- (11) CARPENTER, H.C.H., 'Metallurgical education of university rank in Great Britain'. Proc. (1st) Empire Mining Metallurgical Congress, part 5, ..., (London: Instn. Mining Metallurgy, 1925), 50.

Half way through the present century the professor of metallurgy at the University College of Cardiff, Professor W.R.D.Jones, was able to claim: 'There is no difficulty in getting vocational training in the works for undergraduates and many works provide a systematic training ... which is of inestimable benefit not merely to the undergraduate but to the future welfare of industry.' Professor Jones went on to observe that, over a number of years, 'the attitude of industry to the university-trained graduate has changed completely from downright antagonism to whole-hearted co-operation'.⁽¹²⁾ The problems inherent in obtaining the co-operation of industry are illustrated by the fact that, while in the 1890s J.O.Arnold of Sheffield was given access to the steelworks in the district, his terms of employment forbade his publishing a book.⁽¹³⁾

A third way in which teaching might be aided was by diagrams, models, and similar visual illustrations of works' practice and environments, together with three-dimensional specimens. Dr.Percy amassed a large collection of such specimens which after his retirement was sold to the Science Museum in London,⁽¹⁴⁾ but materials of these kinds required time, money, and contacts to acquire, and space to retain.

In view of these considerations, let alone others, it can be imagined that the standard of teaching in many of the smaller, less-advanced evening classes was scarcely adequate. It was probably given by a poorly-informed chemistry teacher or by a part-timer drawn from a local works. However, it is likely the students in such situations would be able to use their own industrial knowledge to help counteract the serious disadvantages posed by the poor teaching.

(12) JONES, W.R.D., 'Presidential address (S.W.)'.
Trans.Instn.Mining Engrs., vol.113 (1953-54), 748.

(13) MUSGRAVE, P.W., 'Constant factors in the demand for technical education, 1860 - 1960'. Brit.Jrnl.Ednl.Studies, vol.14, no.2 (May 1966), 185.

(14) CACKETT, Susan, 'The Percy collection - a unique view of metallurgical evolution'. Metallurgist Materials Technologist, vol.11, no.2 (Feb.1979), 79-81.

If there were difficulties and shortcomings in providing satisfactory formal instruction in the subject, a convenience of placing metallurgy tuition within a chemistry department was that much of the practical laboratory exercises could be devoted to methods of chemical analysis. At their best, such analytical techniques could provide a valuable method for imparting a good deal of information and understanding of chemical metallurgy principles. They could throw light, for example, on why some metals such as aluminium and zinc might be expected to be more difficult to extract from their ore minerals, and to require the input of more energy in the process, than others like copper and gold; similarly they could illustrate how the occurrence of harmful corrosion reactions in service might be minimised. However, advantage was not always taken of the pedagogical opportunities afforded, so that sometimes 'metallurgical analysis' was presented as an art whose principles were completely divorced from practical large-scale industrial operations: this was the case even within the Royal School of Mines halfway through the present century.⁽¹⁵⁾

An advantage resulting from a detailed knowledge of the recipes for chemical analysis coupled with practical manipulative skill was that they had market value, being useful for determining the compositions of the various raw materials, intermediates, and final products of works. Because analytical skill had commercial value, and because the acquisition of such skill fitted conveniently into the chemical basis of the teaching and matched the equipment used for instruction, in a fair proportion of classes this aspect was taught at the expense of others. Professor J.O.Arnold's speciality in the University of Sheffield in the opening years of the present century was such metallurgical analysis. He personally devised and

(15) ALMOND, J.K., personal experience, 1949-1952.

developed several techniques, and the analytical-chemistry laboratories of Sheffield's applied science department could accommodate more than a hundred students at once. Similarly at the Royal School of Mines Dr. Percy was known as a competent analyst, as was his assistant Richard Smith, and his students on qualifying could be assumed to be proficient in this branch of skilled art. This would also be the case with pupils who underwent periods of four-years' training with professional analytical chemists such as William Baker ARSM in Sheffield and J.E. Stead in Middlesbrough. In some quarters, though by no means all, this philosophy persisted, so that at the Royal School of Mines until after 1950 a substantial portion of the metallurgy course continued to be devoted to assaying and metallurgical analysis in the belief this would give the student something of value to potential employers. The thinking implicit in this century-long style of instruction was that, once the qualified person had secured a job, it was up to him by his individual qualities to win the confidence of his employer and exploit the opportunity to make sure he advanced in his career.

There are many instances where metallurgical instruction was given in close association with a chemistry department; indeed, of ten or twelve major nineteenth-century academic institutions existing in England and Scotland in 1891, no less than five offered metallurgical teaching within departments of chemistry: University College Liverpool, Mason Science College Birmingham, Owen's College in Manchester, Durham College of Science in Newcastle-upon-Tyne, and the Watt Institution in Edinburgh. In addition, in Nottingham at the opening of the University College in 1881, Frank Clowes, the man appointed head of chemistry, held the title 'professor of chemistry and metallurgy'; in 1895 at the same college a lecturer on 'chemistry and metallurgy' was added to the staff. Only in London, at King's College as well as the Royal School of Mines, at the Technical

School in Sheffield, and in the Technical College in Glasgow, four places in all, were 'professorships' in metallurgy established before 1891, and three of these were founded in the 1880s, already one third of the way through the period 1851 - 1950. A high proportion of college metallurgy courses made their appearance between 1882 and 1900.

In the new century the linking of metallurgical tuition with chemistry departments continued. Thus, at Woolwich Polytechnic there was a joint department until 1927, when metallurgy was dropped from the title. At Northampton Polytechnic Institute in London metallurgy was taught in the department of applied chemistry until after 1950: the subject was later to be transferred to the department of mechanical engineering. At the Chelsea Polytechnic a 'school of metallurgy ... formed an important section of the department of chemistry for many years' until, in 1939, it was moved to Battersea Polytechnic 'owing to the increasing importance of a closer association of the study of metallurgy with engineering'.⁽¹⁶⁾ In the University of Oxford, the single individual clearly identified with metallurgy in the 1930s and 1940s was Dr. William Hume-Rothery: he was accommodated within the chemistry department.

These joint departments were products of expediency at a period when, judged by the standards of the 1960s and 1970s, numbers of full-time academic staff employed were meagre. At least until the 1920s, a high proportion of the full-time college staff teaching metallurgy had been trained at the Royal School of Mines and would therefore be imbued with the idea of metallurgy as an extension of chemistry, and there were undoubted conveniences in basing many of the practical metallurgical exercises upon the equipment available in a chemical laboratory.

(16) QUINSEE, A., personal communication, 1977; quoting Annual Report for 1938-39 of Chelsea Polytechnic.

The close association between metallurgy and chemistry had adverse effects: the real shortcomings of the confined chaperoning of academic metallurgy by chemistry were that it provided no strong links with engineering, and in the eyes of potential employers it identified the graduate with chemistry. Thus, the departmental committee which investigated British trade and industry in the 1920s was evidently unaware of any worthwhile distinction existing between the two subjects. In the section of its reports which considered the facilities for training technical staff for the iron-and-steel industry it noted 'there are ... courses in various branches of chemistry and metallurgy in all the principal universities ... also technical schools ... in which full-time day courses in chemistry ... are provided. These courses may or may not include iron and steel or metallurgy'. The committee was able to conclude its paragraph in a relieved way, however, by observing reassuringly that 'in any case ... (these courses) provide a sound training in chemistry and allied subjects.'⁽¹⁷⁾ On the one hand those who had received metallurgical tuition were expected to perform the functions of chemists, and on the other it was common to find the works' chemist put in charge of 'metallurgy' even if he had had no relevant formal training.

Like the subject of chemistry, the scope of engineering widened and grew considerably during the hundred-year period, and metals formed a vital part of the developments. In the years before 1900 Roberts-Austen and his small band of collaborators, in carrying out investigational work on alloys sponsored by the Institution of Mechanical Engineers, made a good start in fostering closer ties between engineering and metallurgy, and during the first half of the twentieth century there came gradual recognition by engineers that metallurgy might be able to contribute answers to questions involving the mechanical

(17) COMMITTEE ON INDUSTRY AND TRADE, Factors in industrial and commercial efficiency being part one of a survey of industries (London: HMSO, 1927), 201.

properties of materials. From time to time metallurgists were invited to give information to the Institutions of Civil and Mechanical Engineers, and in 1908 engineers were prominent in the formation of the Institute of Metals. Some engineers acknowledged the importance of metallurgy, as for instance Sir Henry Fowler, chief mechanical engineer of the London, Midland and Scottish Railway Company, in his presidential address to the Institution of Mechanical Engineers in 1927. Sir Henry suggested that much of his own appreciation of metallurgy might well have stemmed from the enthusiasm of the teacher of the subject he encountered in 1885-87 while pursuing the mechanical-engineering course at the Mason College in Birmingham.⁽¹⁸⁾ The teacher was Thomas Turner ARSM, who was appointed lecturer on metallurgy within the department of chemistry in 1886; after the Mason College had become the University of Birmingham, in 1902 he was appointed professor of metallurgy. Sir Henry also observed that he had been impressed by the small amount of metallurgical knowledge shown by engineering graduates who came for their practical training to the works he controlled: he considered such knowledge essential for mechanical engineers, 'who deal ... with metals, their properties, and the effect of heat and fluids on them'. He stated that 'metals, and the physical state in which we are able to use them, dominate our work. Our whole profession is dependent on them, ... mechanical engineering only commenced when metals became available for our use.'⁽¹⁹⁾ In the USA, twenty years later, one publicised opinion which it was claimed represented the consensus of engineers both in industry and in education was that 'all engineers, particularly the mechanical, need a strong course in metallurgy'.⁽²⁰⁾

(18) FOWLER, Sir Henry, 'Address by the president'.
Proc.Instn.Mechanical Engrs., (1927), vol.2, 725.

(19) FOWLER, Sir Henry, op.cit., 725, 726.

(20) GUY, A.G., 'Metallurgy in the mechanical engineering curriculum'. Jrnl.Engng.Edn., vol.39, no.5 (1948) 288; quoting CARMICHAEL, C., 'The future of mechanical engineering education', Jrnl.Engng.Edn., vol.36 (1945-46), 55-65.

As a corollary of the increasing knowledge of metals' engineering properties which took place more particularly after 1890, within the subject of metallurgy there was a decline in the relative importance of metal production. Nonetheless, in 1924, of the ten British universities which accepted metallurgy for the award of degrees (awards at Cambridge being confined to higher degrees obtainable by research), seven considered the subject to lie within the faculty of science or applied science, while only two, London and Liverpool, placed it within the engineering faculty; Sheffield had an individual faculty of metallurgy.⁽²¹⁾ For the first three quarters of the period 1851 - 1950 the British academic world had little time or sympathy for metallurgy, which was regarded as lacking the philosophical discipline and challenge afforded by 'pure' physics and chemistry, in addition to being tainted by close industrial connotations. However, in the quarter century from 1926 to 1950, with the development of experimental techniques such as x-ray diffraction, coupled with the advent of the electron microscope and stimulated by advances in theoretical understanding, physicists were attracted to the problems posed by the structure of metals and alloys. These physicists provided considerable help in determining the underlying factors which controlled metallic structures, but their influence within academic departments led to the promotion of theoretical advances at the expense of other facets, so that chemical, economic, and engineering features of the subject became subordinate, or even completely squeezed out from curricula. The full effects of this influence were to become manifest in the later 1950s when those who graduated from British metallurgy courses knew a good deal about the theoretical structures of metals and alloys, but little about practical plant operations, economic considerations, and the commercial production of metals. Such a situation was certainly in accord with the long-cherished British desire

(21) CARPENTER.H.C.H., op.cit., 48.

that 'education' should concentrate on general principles rather than attempt to have vocational value. However, one university teacher of long experience, speaking soon after 1950, stressed that metallurgy was 'primarily an industry'. He gave the timely warning that although the subject was aided by technology and science 'it is inadvisable to exaggerate the role of physics ... since in this way a part is inflated until it looks like the whole, and ends are lost sight of in the admiration of means.' (22)

Unfortunately, the job prospects of those who studied metallurgy were not good: in the Royal School of Mines' opening years only a minority of students who took the metallurgy course found employment that was directly relevant with more, in the aggregate, going into non-metallurgical occupations such as dyeing and brewing. Doubtless the large majority of those who passed the Science and Art Department's examinations in metallurgy in the years before around 1910 similarly derived little immediate financial benefit. Indeed, in some cases employers tried to prevent men from attending the courses. Thus there was small incentive for succeeding generations to become 'educated' in metallurgy, and the demand for suitable formal instruction remained at a low level until the short-lived post-war boom of 1919.

It seems clear that the main cause of the pathetically-small growth in metallurgy instruction during the period 1851 - 1950 was apathy, or even in some instances downright hostility, of potential employers. Several reasons can be adduced as contributing to their attitudes. The majority of proprietors of industrial works involving metallurgy were unwilling to recognise the advantage of employing those who had received formal instruction. Not only did they fail to appreciate the positive attributes which such a person might bring to his work, but many were suspicious of those who had undertaken 'book' learning

(22) ROBERTSON, J.M., In discussion of his paper, 'Some metallurgical aspects of engineering'. Bull.Instn.Metallurgists, vol.3, no.2 (May 1951), 21.

outside their own working situation, and at the same time they were openly hostile to the idea of admitting such unknown quantities inside their works, where trade secrets might be acquired for subsequent sale to rivals.⁽²³⁾

This almost complete lack of inducement for metallurgical instruction contrasts sharply with the situation in the mining industry where from 1873 Government legislation made 'certificates of competency' a prerequisite for responsible employment in British coal pits. Whatever the shortcomings of the certification system in its early years, the legislation produced on the part of both colliery proprietors and ambitious employees a marked desire for the provision of suitable instruction. As a result, by 1913 technical classes in subjects related to mining coal had become important at a number of centres in Britain. Moreover, after 1920 and the introduction of the miners' welfare scheme, coal-mining instruction at various levels received financial help from the compulsory levy on all coal produced. While the economic importance of the British coal industry was firmly recognised by all concerned, as was the social status of the colliery official, the situation was radically different in the branches of metallurgical industry, where works and working practices were largely unregulated and people with metallurgical training had no well-defined positions either technically or socially. Thus there was little encouragement, either from employers or from employees, for the provision of metallurgical instruction. This conclusion, which is in general agreement with a view advanced in 1966 by P.W.Musgrave, contrasts markedly with a passage in the Crowther Report of 1959 which concluded on technical education that 'virtually everything that exists ... has come ... as the conscious answer to a demand arising from industry or from individual workers'.⁽²⁴⁾

(23) MUSGRAVE, P.W., op.cit.,

(24) MUSGRAVE, P.W., op.cit., 177; quoting MINISTRY OF EDUCATION: CENTRAL ADVISORY COUNCIL FOR EDUCATION (ENGLAND), 15 to 18, (HMSO, 1959), 333.

True, the gradually-increasing complexity of certain processes, such as steelmaking, combined with the need for proprietors to improve the quality and reliability of their products to remain competitive, led to some job opportunities for those able to carry out routine quality determinations by chemical analysis, and this was one of the main fields open to metallurgical graduates for the first two thirds of the period 1851 - 1950. In this limited field it seems likely that a high proportion of the tasks could be done just as well by trained analytical chemists as by metallurgists, so there would be direct competition between those who had pursued metallurgical training and those who had not specialised in that direction.

For two thirds of the period or even longer, the view prevailed among British industrial employers that college-trained men had nothing to offer, and consequently job prospects for them were bleak. The employment market for those with metallurgical training was not helped by the poor economic climate which persisted in many sectors of the metal industries at various times, such as the last fifteen years of the nineteenth century and during the 1920s and early 1930s. Moreover, a fair proportion of overall industrial activity was accounted for by the efforts of relatively-small organisations. Around 1910 the influence of academic metallurgy departments situated in manufacturing districts, such as that of the University of Birmingham, began to make itself felt. It was a regrettable fact that, at any rate until that time, an academically-qualified 'metallurgist' did have little to offer a potential employer as far as the working and manipulation of metals were concerned. This was because of the comparative neglect of such working processes by the nineteenth-century metallurgy syllabuses, a neglect stemming in part from the disinterestedness of industrialists as well as from the overlap of this part of the subject with 'engineering', and from the need to appear to avoid imparting 'trade' instruction.

After 1920, although commercial job prospects within Britain remained adverse, the scope for metallurgical work widened somewhat. Employment opportunities for those with academic training in metallurgy increased as the Government-inspired Department of Scientific and Industrial Research (DSIR) brought into being industrial research organisations. Additionally, the DSIR channelled public funds into the stimulation of relevant research in academic departments; in this way small numbers of research students were supported during the thirty years from 1920, while at the same time the academic departments concerned were helped to remain open. Particularly during the 1930s with the associated small numbers of undergraduates who came forward for training, this Governmental financial support was of substantial value. The DSIR itself was a product of the Great War of 1914-18, and by the advent of the Second World War of 1939-45 its policies were becoming accepted as yielding useful results. In the field of metallurgy during the last two decades of the period before 1950, active industrial research associations existed for the iron-and-steel industry, for ferrous foundrywork, and for non-ferrous metals. Not only did these associations themselves provide some limited opportunities of livelihood for those with metallurgical training but by their example they encouraged individual companies to employ similar people. An outstanding example was the United Steel Companies Ltd., which devoted £20 000 a year to research.

In the final decade before 1950 opportunities for those with metallurgical training increased considerably, the main reason for this change of prospect being the war. Primarily the war gave rise to demand for greatly-increased quantities of metal products of all kinds and hence generated the need for skilled people to produce them successfully. Such strategic items as ships, tanks, aircraft, communications equipment, and armaments

were all fundamentally metallic. Secondly the war of 1939-45 led to public reappraisal of the value of technology to the community, so that following it State funds were made available to enable greater numbers of students than formerly to attend academic courses. From these causes the number of British metallurgy graduates rose from less than twenty-five in 1938 to more than 75 ten years later, and numbers were to continue to rise to exceed 100 soon after 1950. The war also stimulated the development of 'atomic' energy, and in the years after 1945 this market absorbed a considerable proportion of new metallurgical output from the universities.

Despite the improved employment opportunities of the 1940s, however, until long after 1950 many of the immediate job prospects for young metallurgical graduates were far from glamorous, with offers from British industry of mediocre pay and gloomy surroundings for performing tasks that lacked responsibility. Small wonder the 'brain drain' was to occur in the late 1950s !

Without doubt wars, and threats of wars, were a major influence on the development of British metallurgical instruction throughout the hundred years 1851 - 1950. Fear of wars led to public funds being made available to maintain national capability and to develop new and better materials and products such as metal-armoured ships, improved guns and projectiles, internal-combustion engines suitable for aircraft, and electronic materials to aid signalling: all of these involved metallurgical skill. Actual hostilities led to sharp increases in metal consumption. The major wars of 1914-18 and 1939-45 also led to reassessments of the kind and scale of technological training that was nationally desirable; the DSIR was an important product of the Great War while among the fruits of the Second World War was the Barlow committee on scientific manpower which recommended drastic increases in university

places. One of the useful services performed by the DSIR was the preparation soon after 1940 of a report on metallurgical training.

At the ends of both major conflicts large numbers of exservicemen came forward to undergo advanced levels of instruction. In 1945, as a result of national awareness of the strategic part played by technology in securing the desired outcome to the war then just ended, for a few years public funds for the encouragement of technology became available in abnormally-large quantities.

By contrast with the beneficial effects upon metallurgical instruction of national military activities, the influences exerted by organised groups were not so clearly defined. It is true that a country-wide learned society for the iron-and-steel industry entitled the Iron and Steel Institute was founded as early as 1869, and continued in existence until after the end of the period under consideration. This body certainly contributed to the advance of the subject of metallurgy but it did little directly to aid the status of those practising it. A significant proportion of the membership of the Iron and Steel Institute consisted of works' proprietors, and the discussion of all matters concerning employment was forbidden. Early in the present century the Iron and Steel Institute found itself administering funds for metallurgical research provided by the Scottish-American steel millionaire Andrew Carnegie. During the war of 1939-44, following the lead given by the DSIR, the Institute produced a report 'The training of metallurgists with special reference to the iron and steel industries'.⁽²⁵⁾ After 1945 the institute also found itself involved in the organisation of a national certificate scheme in metallurgy, but it did not attempt to champion the cause of metallurgists.

(25) IRON AND STEEL INSTITUTE COUNCIL, 'The training of metallurgists with special reference to the iron and steel industries'. Jrnl.Iron Steel Inst., vol.149 (1944), pt.1, 601P-631P.

Forty years after the founding of the Iron and Steel Institute there was created another national society, the Institute of Metals. This was concerned with non-ferrous metals and, by its situation within Britain, was therefore primarily devoted to the topics of metals' fabrication, working and, increasingly, with structure. Corrosion research also came under its aegis. Like the older national society, the Institute of Metals did much useful work in publishing technical information relating to metals and in providing social opportunities for those involved in the metal industry to meet. Again, however, no business relating to employment was entertained. In the proceedings of both societies people engaged in engineering took substantial parts.

Membership of the Iron and Steel Institute and the Institute of Metals was largely unrestricted, so to obtain a mark of professional ability those working within the metal industry had to turn elsewhere. For 95 years of the hundred-year period the available alternatives were the Institute of Chemistry and the Institution of Mechanical Engineers, for membership of both these bodies provided personal qualification. In the years around 1950, successful completion of the metallurgy course at the Royal School of Mines was granted partial exemption from the qualifying examinations of the Institute of Chemistry, an examination in organic chemistry being necessary to satisfy the conditions for membership.

It is a sad measure of the relatively-small numbers of metallurgically-trained people in Britain, and of their inconsequential status within industry, that it was not until 1945 that an Institution of Metallurgists came into being: in marked contrast with the existing learned societies this had the object of furthering the interests of those who tried to make livings as metallurgists. This it did by setting well-defined standards for membership. As a consequence, the Institution

of Metallurgists took an active and direct interest in metallurgical education, participating in the national certificate scheme then being launched, and shortly afterwards setting up its own system of examinations for the various grades of membership. It is worthy of note that this system was not confined to Britain, examination centres being extended to parts of the Empire such as India and Australia. A good deal of the inspiration for the formation of the Institution of Metallurgists seems to have come from members of the Birmingham Metallurgical Society. In view of the fact that the Institution of Metallurgists did not materialise until the last few years of the period 1851 - 1950 the influence that it could bring to bear by 1950 was limited, but nonetheless substantial: the institution suggested that those who practised metallurgy were worthy of professional identity in similar fashion to engineers, chemists, and lawyers, and it rapidly identified itself with standards in metallurgical instruction.

It was not only organisations predominantly interested in metallurgy which exerted significant influence on the development of instruction in the subject. Features of metal production and properties were included in the deliberations of a number of other societies and reached wide availability through their printed transactions or proceedings. The Institutions of Mechanical and Civil Engineers both furthered the spread of metallurgical understanding, as did the Society of Chemical Industry and the Faraday Society. Moreover, the Institution of Civil Engineers showed concern for engineering training, issuing several statements during the period under consideration. In 1906 the report of a joint committee on engineering education and training initiated by the Civils recommended that, for a career in the higher levels of engineering, tuition of five or six years was appropriate for a person who left

school at seventeen; about one half of this time should be spent in formal academic studies and the other part in on-the-job industrial training. The report also clearly identified one of the chief weaknesses of British technical training: this was the fact that employers were generally unsympathetic and unhelpful.⁽²⁶⁾

On a wider front, and aiming largely at those who were not born with the advantage of being able to undertake extended tuition before earning a livelihood, the activities of the City and Guilds of London Institute had notable impact in the years after 1880. The City and Guilds' system of technological examinations encouraged the growth of evening instruction and contributed to the development of local technical colleges. Among the subjects in which examinations were offered was metallurgy but, as with the Science and Art Department's endeavours, the numbers involved in this were always comparatively small.

In general, factors which have influenced metallurgical instruction in England and Wales may be categorised as either 'economic' or 'social'. As always, it is difficult to draw a sharp dividing line between the two categories and to put all influences definitely within one or other of them. However, as with all technological subjects, instruction in metallurgy was sought by individuals to improve their job prospects, and it was provided by various agencies to enhance economic competitiveness.

As far as social influences are concerned, they mainly had a discouraging effect upon metallurgical instruction. In this they reflected the popular image of the occupation of metallurgy as involved with industry which was commonly rough, noisy, and dirty. Because the field of 'metallurgy' was ill defined and

(26) INSTITUTION OF CIVIL ENGINEERS, 'Education and training of engineers. Report of a committee ...'.
Trans.Instn.Mining Engrs., vol.30 (1905-06), 499.

poorly perceived by both employers and many of those within it, it is not surprising that the public at large should have only a vague conception of what it entailed. In sharp contrast with the Continental metallurgy graduates of the nineteenth century who had well-defined social status and officers' uniforms to display it, British metallurgy graduates had neither status nor uniforms.

Because of its close association with heavy industry the pursuit of metallurgy would be stigmatised by schoolmasters; on the one hand generations of school science teachers must have misrepresented it through ignorance, while on the other it would meet with the traditional contempt shown by grammar-school headmasters for any pupil rash enough to consider studying a technological subject at a civic university or university college. One exception around 1950, which presumably merited recording because the message was so uncharacteristic, was the chief master of King Edward's School in Birmingham who, in his Founder's Day speech, 'urged his boys to consider technology as a (possible) ultimate goal, pointing out that it was ... in the national interest that some of them should enter this field.'⁽²⁷⁾

Not only at school but likewise at home, any youth seeking to undertake metallurgical instruction might evoke parental hostility stemming from the middle-class desire to keep the next generation away from sordid industry and instead to guide it into respectable white-collar jobs. A further factor which might guide a schoolboy of high intellectual standard into a 'pure science' department of a university rather than into applied science or engineering was the natural inclination to continue studying in a subject which the individual already knows and in which he has already demonstrated his ability.⁽²⁸⁾

(27) WRIGHT, T., 'Fifty years of progress in metallurgical education'. Jrnl.Birmingham Metall.Soc. Golden Jubilee Issue (1954), 122.

(28) WRIGHT, T., loc.cit.

In addition to these social pressures which might be brought to bear by contact with other people, the individual might be dissuaded from starting metallurgical study by inanimate influences such as the sights and sounds of local industry, conveying a clear impression of undesirable gloom and dirt, or by the accounts printed in local-newspaper reports. In contrast with these factors, however, it might be expected that metallurgical descriptions contained in books and periodicals would be more likely to act as incentives than as deterrents, stimulating the reader to get to closer grips with the subject. In this respect metallurgical industry showed a marked change of attitude in the last few years of the period 1851 - 1950, bestirring itself to publish recruiting literature. This publicity was channelled from two sources, the joint education committee of the relevant national learned societies and professional institutions, and the British Iron and Steel Federation composed of works' proprietors. The joint education committee in 1946 published a 38-page booklet entitled 'Metallurgy a scientific career in industry', which set out to inform schoolmasters and all others who might be interested what metallurgy was about, what career prospects it could offer, and how a schoolleaver could obtain formal tuition to equip him to enter the field. By the nature of its interests, the British Iron and Steel Federation, through its training committee established after 1945, was concerned with only a limited sector of the field, but within this it set out to woo schoolleavers for jobs of all kinds, in commerce as well as in technology, by means of illustrated brochures. At the same time the federation's training committee initiated extensive programmes for training within the various steel-making districts, taking advantage of the Government's encouragement of such activities by the newly-constituted Youth Employment Service.

Some of those grammar-school leavers of the 1930s and 1940s who went on to pursue an undergraduate course in metallurgy were influenced to do so because their performance in mathematics was not good enough to enable them to study the physics or chemistry they would have preferred. Even one third of the way through the century 1851 - 1950, the Royal School of Mines was criticised for its lack of mathematical facilities. While the situation was improved subsequently by use of the expertise in the neighbouring Royal College of Science with its department of mathematics, it could still be stated by an academic with experience of the school in the 1930s: 'I have often felt that many people become metallurgists instead of engineers because by doing so they are able to drop any concern with mathematics at an early stage in their career'.⁽²⁹⁾ Yet another factor influencing choice was national economic climate, for in the years of depression in the 1920s and 1930s young men tended to seek 'safe' occupations such as teaching, for which a college course in metallurgy was likely to be of less use than one in many other subjects.⁽³⁰⁾

Attempting to summarise the chief factors which influenced metallurgical instruction in England and Wales in the period 1851 - 1950, first of all it can be stated that Government actions through the education office had a background effect which in the long term was highly beneficial. Such actions supplied general schooling as the first step towards technological instruction, and through the Science and Art Department's classes and examinations supported national tuition in metallurgy in company with that in a score of other subjects. Throughout the whole period there is evidence of national

(29) ROBERTSON, J.M., op.cit., 8.

(30) WRIGHT, T., op.cit., 115.

concern for 'commerce and trade' and of this being the cause for the expenditure of public money to encourage scientific and technological instruction. Treasury grants were made from 1889 in increasing amounts to help a number of universities and university colleges which came into existence as the result of local social and philanthropic forces. Benefits for metallurgy, however, came only as an incidental effect of the overall increased Government support for education: the subject received no specially-favoured treatment whatever.

Military influences were important in bringing about Government action to improve the opportunities for general education and technological instruction. State military activities also provided a significant proportion of jobs for those possessing formal metallurgical training, although more came from industry. Springing from joint military and civilian State needs was the DSIR, through which there came important aid for metallurgical instruction during the 1920s and subsequently. This acted in two ways: firstly it promoted industrial interest in metallurgy and developed industrial demand for the services of trained metallurgists; secondly the DSIR helped academic departments of metallurgy.

The fundamental problem, at any rate for the first three quarters of the period 1851 - 1950, was that employment openings were meagre for those possessing formal metallurgical training. Unless as chemists, with few exceptions British industry did not consider such people worth hiring. Clearly this exercised a markedly-adverse influence: as no significant economic incentive was provided by employers, little demand for instruction arose either from them or from those who might be employed. Thus, although by 1920 metallurgical tuition was offered in about a dozen of the civic universities and university colleges which had by then come into being, it lacked popularity in the eyes of staff, students, and local employers.

Formal metallurgical education in England and Wales began in connexion with the Great Exhibition of 1851, receiving encouragement as one of the few subjects in which tuition was offered by the new Government School of Mines. As Dr. John Percy, the lecturer on metallurgy, commented at the time,⁽³¹⁾

'I know that men (presumably foreigners) who have received a metallurgical education on the continent are now employed in metallurgical establishments in this country; and I know many instances of English students seeking that instruction in mining and metallurgy abroad which had not been provided for them at home.'

Eleven years later metallurgy was given further stimulus as one of the courses sponsored by the Science and Art Department. However, for a number of reasons, among them the relatively-great difficulty in supplying instruction in the subject and the boycott by industrial employers, 'metallurgy' did not prosper to anything like the extent of the 'pure' subjects physics, chemistry, and mechanics.

However, even if formal instruction in metallurgy did not flourish, the subject underwent great expansion during the century 1851 - 1950, and this involved substantial changes in emphasis of the relative importance of the various sectors; potential employers and teachers alike tended to be confused by these changes. Another difficulty faced by those who tried to determine the components which would provide an appropriate course of tuition was caused by the fact that 'the majority of metallurgists ... are such by the forces of circumstances and of habit, rather than by reason of any special aptitude for the profession.'⁽³²⁾

The leading American metallurgical academic, Professor John Chipman of the Massachusetts Institute of Technology, claimed in 1949 that 'metallurgy is a field of great breadth' with many

(31) PERCY, John, 'On the importance of special scientific knowledge to the practical metallurgist ...'.
Records School of Mines (Geol. Survey Great Britain),
vol.1 (1852), 136. (op.cit.)

(32) AITCHISON, Dr.L., 'The presidential address ... on metallurgical training and the society'.
Jrnl.Birmingham Metall.Soc., vol.9 (1925), 610, 609.

common frontiers, and drawing heavily upon both of the two basic sciences physics and chemistry. Equivocally, he described metallurgy as 'a branch of engineering' and at the same time 'a field of applied science'.⁽³³⁾ British academic thinking tended to be similarly unsure. Thus, the publicity booklet sponsored in 1946 by the joint education committee of the metallurgical societies described the subject in its title as 'a scientific career in industry', and repeated in the text that 'the metallurgical industries are seeking first-class scientists in greater numbers ...'.⁽³⁴⁾ Yet by 1953 a lengthy report by the same joint committee was said to stress that metallurgical graduates 'are educated but not trained technologists'.⁽³⁵⁾

It is suggested that this ambivalence engendered by the subject was metallurgy's own worst enemy to progress during the century before 1950. At the beginning of the period it held great promise, but during the succeeding decades neither academics involved with administering teaching institutions nor potential employers concerned with using the product were entirely clear what the subject entailed. In the USA there developed some sympathy for the notion of the 'metallurgical engineer' rather than the 'metallurgist', but in Britain there persisted general hostility to this idea. In the years before about 1930 the opposition was based on the close association of the subject with chemistry in the nineteenth century, coupled with its failure to establish any well-defined field of its own which might be readily identified with 'engineering'. In the last two decades of the period under consideration, however, the active lobbying against the idea of metallurgy as an engineering discipline came from the small number of chemists and physicists who had moved into influential positions in the sector of the field concerned with metallic structure and properties and were anxious to cultivate it as a branch of 'pure' science.

(33) CHIPMAN, John, 'What is metallurgy?'.
Metals Trans.(AIME), vol.185 (June 1949), 354.

(34) PAYNE, F.Lewis, Metallurgy a scientific career in industry.
 (London: Joint Committee on Metallurgical Education,
 1946, 1948), 3.

(35) A.D.M., 'The Board of Metallurgical Studies and Examinations'.
Bull.Instn.Metallurgists, vol.4, no.3
 (Aug.1953), 18.

In consequence of the ill-perceived scope of the subject and the lack of any vital industrial value that might be attributed to the possessor of knowledge of it, the person who had received metallurgical instruction lacked a definite identity. Because no professional body for metallurgists existed until the second half of the 1940s, and because there was no other strongly-influential agency to champion the cause, during the previous decades the subject repeatedly lost ground to the other disciplines that were growing up round it. These were branches of chemistry on one side and sectors of engineering on the other. Thus, while substantial development of metallurgical instruction took place in the period 1851 - 1950, by no means all the influences were beneficial.

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List of Informants

The following people have supplied information incorporated in the text of the thesis, although in all cases the interpretation placed on the material is that of the writer.

Anderson, A., of Heriot-Watt University in Edinburgh

Carter, Dr.J.H., Principal Lecturer in Chemistry at the
Royal Naval College, Greenwich

Charles, Dr.J.A., Reader in Metallurgy in the University
of Cambridge

Cowley, Dr.F.G., Sub-Librarian in the University College
of Swansea

Dowson, Dr.A.G., formerly Professor and Head of the Department
of Chemistry and Metallurgy at the Greenwich Royal Naval
College

Edwards, Dr.M.R., ARSM, of the Metallurgy Branch, Royal Military
College of Science, Shrivenham, Wiltshire

Elliott, F.B., Senior Lecturer in Charge of Metallurgy
at the City University in London

George, Commander G.C., RN, Head of Department of Engineering
Materials in the Royal Naval Engineering College, Manadon,
Plymouth

Harrison, James, of the Patent Office in London

Jones, Josiah W., formerly Head of the Materials and Metallurgy
Section, Cranfield College of Aeronautics, near Bedford

Kennedy, Dr.A.J., formerly Head of the Department of Materials,
Cranfield Institute of Technology (formerly College of
Aeronautics)

Kennett, Dr.S.J., ARSM, formerly Senior Lecturer and Acting Head
of the Department of Metallurgy and Materials Science in
the University of Liverpool; author of A history of the
department of metallurgy and materials science, University
of Liverpool 1920 - 1970

Leach, Professor J.S.Llewelyn, Cripps Professor of Metallurgy
in the University of Nottingham

Ledgard, A.T., formerly Senior Blast-Furnace Manager with the
British Steel Corporation

Maxwell, D., of the Department of Metallurgy in the University
of Newcastle-upon-Tyne

Quinsee, A., Librarian of Chelsea College in London

Schofield, G.A., Secretary of the Institute of British
Foundrymen

Sears, K.A.E., Information Officer of the City and Guilds
of London Institute

Smith, Dr.A.E.W., formerly Head of the Metallurgy Branch of the
Royal Military College of Science at Shrivenham in Wiltshire

Thackray, J.C., of the Geological Museum in London

Watson, Dr.J.H., ARSM, MC, CBE, formerly Chemist and Assayer
to the Royal Mint

Wickstead, A., formerly Director of Education for Lindsey
County Council, Lincolnshire

