

BIOGRAPHICAL MEMOIRS

Norman Percy Allen, 1903-1972

Sir Charles Sykes, F. R. S.

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NORMAN PERCY ALLEN

1903–1972

Elected F.R.S. 1956

BY SIR CHARLES SYKES, F.R.S.

NORMAN PERCY ALLEN was born on 5 June 1903, at Wrexham, North Wales, and was the fifth of ten children, seven girls and three boys.

His father, Sidney Edward Allen, was an accountant who was employed in the Borough Treasurer's Department at Wrexham at the time of Norman's birth. He was one of the large family of a sculptor whose work was mainly on churches and other public buildings. In 1908, he became accountant to the Local Authority at Sheffield and in 1912 was appointed Borough Treasurer of Burton-on-Trent where he lived for the rest of his life. A deeply religious man, he was a very keen, active member of the Congregational Church and a local preacher. His children were all expected to take their part in Church activities and family life was much influenced by his insistence on its principles. This undoubtedly had a strong effect in shaping the characters of all his children.

His mother, born Emily Davis, was a kind, intelligent, essentially practical person—very skilled in the domestic arts and an expert dressmaker. Care for her large family, who were very close together in age, left very little time for outside interests other than the Church. Little is known of her family, the remaining members of which are now in Canada.

In a large and rather boisterous family, Norman is remembered as the quiet brother who was often absorbed in a book (he was a prolific reader) or in one of his succession of hobbies. He had, however, a keen sense of fun, one expression of which was in the nonsense verse he used to write and illustrate. This later developed into an interest in more serious poetry. While at Swansea University College one of his poems won a bardic chair in a minor local eisteddfod. When very young, he kept a small aviary for his collection of British birds. Later, he taught himself to do fretwork and painstakingly produced some very complicated models which must have demanded endless patience. This was followed by wood carving, and again he made various objects for the house, decorated with quite impressive detail. He enjoyed walking, covering long distances at a great pace. He was a member of his school Natural History and Archaeological Societies, activities which fitted in well with his long country walks.

EDUCATION

Allen was educated at Ranmoor Elementary School, Sheffield, up to the age of ten and then, when the family moved to Burton, he entered the Burton-on-Trent Boys' Grammar School and was there from 1913 to 1920. His school record was a good one. He gained a first class honours certificate with five distinctions in the Cambridge Junior Local Examination and in the Higher School Certificate Examination he gained the mark of distinction in chemistry. He was awarded the Linley open scholarship at Sheffield University, one of its premier awards. At school, he was keen on games and made an excellent house captain. He was in the school XV for rugby and was a first-class swimmer. His headmaster attributed the success of the school rugby XV during Allen's period as being largely due to his efforts. He held a commission in the School Cadet Corps and made an excellent officer.

It is not clear why Allen decided to study metallurgy. He is known to have complained about the lack of advice available at the Burton school relating to future careers. It appears that the Sheffield scholarship examinations were the only ones he sat. His chemistry master had worked in a Sheffield steel works during the 1914-18 war, and Allen had retained friendships from his schooldays with people in Sheffield who were connected with both the ferrous and the non-ferrous industries in Sheffield. It is conceivable that he was influenced by these contacts and his early period in Sheffield.

At Sheffield, he studied metallurgy under Professor C. H. Desch. He obtained a second-class honours degree and was also awarded the Associateship in Metallurgy which at that time was not generally given to full time students. He played rugby at the University and was awarded his colours, but did not continue with competitive swimming. He was a prominent member of the Debating Society at the local Congregational Church and took full advantage of the proximity of the Peak District to indulge his liking for walking.

Conditions in the metallurgical industries were difficult in 1923 and grants for postgraduate research were very limited, so Allen was probably pleased to be able to join, after graduation, a small research group at the University working on low-melting-point die-casting alloys. This research, which formed part of a comprehensive programme on die casting alloys generally, had been initiated by the Department of Scientific and Industrial Research and was under the aegis of the British Non-ferrous Metals Research Association. The object of the work was to determine in an authoritative and reliable manner the properties that could be relied upon as obtainable in die castings. The work at Sheffield dealt with zinc base die castings and examined primarily such matters as strength, porosity and permanence of dimensions, particularly under mildly corrosive conditions. Allen's part of the work involved an examination of the flow behaviour of the alloys under stress and in this connection he built an apparatus for observing the effect of stress on the colour bands produced in small celluloid specimens. He carried out investigations on twinning and intergranular corrosion.

He was well liked by the other members in the postgraduate laboratories. He had the reputation of being very reticent and hard working, only occasionally breaking his reserve to join in discussions on rugby football or to refer to some article in *Punch* which particularly amused him.

SWANSEA AND BIRMINGHAM

Shortly after Allen joined the team, the work was curtailed and in November 1925 Allen left Sheffield for Swansea University College where he replaced W. E. Prytherch as an investigator for the B.N.F.M.R.A. working on the porosity of copper and copper alloys.

Allen remained at Swansea for about three years. He retained his reputation of being a hard worker and took a keen interest in the activities of the Metallurgical Society, and his performance at its discussions enabled Professor C. A. Edwards to predict that he would make a very proficient lecturer. It was at Swansea he met Miss Olive Williams, his future wife. She was a native of Swansea and both were members of the same Congregational Church and its tennis club. Her father was a tinplate and metal merchant in Swansea and the family consisted of three sisters.

Since graduating, Allen's financial circumstances had not been easy. This position was improved when he was appointed as an Assistant Lecturer at Birmingham University. He joined Birmingham University in September 1928, and was married in September 1929.

In Swansea, his main relaxation appears to have been walking. Allen suffered from simple myopia and by this time he found it necessary to use spectacles, which would have made it difficult for him to play ball games competently.

He continued his researches on copper alloys at Birmingham under Professor D. Hanson. At this time, Hanson was in the early stages of transforming the courses based on the old extraction and production biased metallurgy by giving more emphasis to metallography and the relation between structure and physical properties. Allen took an active part in these developments and maintained throughout his subsequent career an enthusiastic and pioneering attitude to the application of physical methods to the solution of metallurgical problems. He joined the local Metallurgical Society and took an active part in its affairs: he was a member of Council from 1930 to 1940, President in 1935 and Honorary Editor of the Journal from 1929 to 1934.

WORK ON COPPER ALLOYS

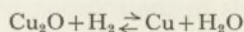
The work started by Allen at Swansea and continued at Birmingham on the porosity of copper and its alloys is reported in a series of papers published between 1929 and 1933. The subject was of great complexity and of considerable industrial importance. Copper was fire-refined initially in the liquid state by oxidation. The oxygen left in the metal was then removed by reduction with hydrogen which is obtained by thrusting green poles or logs below the liquid surface of the metal. If the metal is underpoled and contains too much oxygen it is found to be brittle in the solid state. If overpoled the metal on solidification

is found to be porous and may rise in the ingot mould as a result of gas evolution. Correctly poled material has a density as cast of 8.5 compared with 8.95 for pure copper, and is referred to as 'tough pitch' copper. This reduction in density is associated with a distribution throughout the solid metal of a very large number of minute holes.

For many years, this process had proved difficult to control and presented a wide range of phenomena which were difficult to interpret, and there was no accepted view as to the relative importance of the various gases present—oxygen, hydrogen, nitrogen, carbon monoxide, carbon dioxide and steam.

In his first paper, Allen describes a series of experiments in which copper was melted under a variety of carefully controlled atmospheric conditions. These showed that copper melted in an atmosphere of hydrogen contained large blowholes when cooled quickly. As the cooling rate diminished, the number but not the size of the blowholes was reduced until finally dense copper was obtained. Similarly, dense material could be obtained by passing either nitrogen, carbon monoxide or carbon dioxide over the metal after hydrogen treatment, or by subjecting the metal to a reduced pressure. These experiments showed that of the various gases examined only hydrogen appeared likely to be responsible for the porosity—this conclusion being in agreement with the known solubilities of the various gases in copper. However, the type of porosity observed was entirely different from that found in commercial ingots.

Allen then showed that the introduction of small amounts of oxygen, *ca.* 0.002%, in the form of copper oxide, into melts containing even small amounts of hydrogen produced finely divided porosity, but when the oxygen was introduced as magnesium oxide sound ingots resulted. He concluded that the action of cuprous oxide was chemical rather than mechanical and, after considering the various reactions which might take place, he thought it most likely that the porosity in overpoled copper was associated with the presence simultaneously of cuprous oxide and hydrogen. The problem was to explain why the porosity increased as the oxygen content diminished. He decided that if the reversible reaction



could take place in molten copper, then this might explain the facts since the greater the amount of Cu_2O in the copper the less the amount of hydrogen at equilibrium. From considerations of the maximum amount of hydrogen which can be retained by molten copper at the melting point from solubility experiments Allen showed that only about 0.01% of O_2 would be necessary to combine with it, an amount which would certainly be present in liquid copper as commercially produced. The porosity would vary with the amount of hydrogen present, *i.e.* with the degree of overpoling. Similarly, by a consideration of the change in the oxygen concentration of the copper successively deposited during solidification, it appeared that the porosity would be distributed between the primary dendrites and in the final metal to be solidified, as in fact is the case.

Allen was not able to measure directly the quantities of hydrogen present in the liquid copper, i.e. less than 0.001%, as a function of the oxide content when in equilibrium. He therefore proceeded as follows. Copper was placed in an atmosphere in which the partial pressure of water vapour was controlled, the hydrogen pressure was determined by diffusion through a platinum tube and when a steady hydrogen pressure had been reached, the metal was cooled and analysed for oxygen. Using well-established data for the solubility of hydrogen in copper as a function of temperature and pressure, he was able to calculate the amount of dissolved hydrogen from the pressure measurements. His initial experiments were carried out at 1150 °C and at a partial pressure of water vapour of 234 mmHg, and these showed that the equilibrium hydrogen content increased as the oxygen content decreased. In a subsequent paper, he describes experimental equipment which incorporated many improvements and the work was extended covering a range of temperature and water vapour concentrations.

Taking a value of 0.05% for the oxygen content of tough pitch copper, Allen showed that the hydrogen content in equilibrium as determined experimentally would give rise on solidification, either as hydrogen or steam, to a reduction in density similar to that normally observed. Similarly, at lower oxygen contents greater porosity could be expected. Allen refers to the fact that the measurements proved 'exceedingly difficult'. In view of the equipment and facilities available at that time (*ca.* 1930) this is an understatement.

Allen then went on to make a comprehensive study of the porosity existing in a range of copper ingots produced in a variety of ways by the use of different deoxidants. He showed that the stability of the oxide products and the type of porosity were related. He also carried out an investigation into the unsoundness likely to be produced over the whole range of copper nickel alloys and showed that even traces of hydrogen would produce unsoundness in the presence of oxygen above certain critical amounts which could be as low as 0.001% oxygen. These critical amounts were related to the solid solubility of oxygen in the alloys and varied with the copper nickel ratio.

In a discussion of this work, Professor Hanson referred to the fact that it was one of the few researches 'in which the principles of physical chemistry and thermodynamics have been applied in detail to metal reactions in and near the solidification range. It is very satisfactory that the general theory has proved applicable to such a high degree of accuracy'.

This work has been described in detail since it brings out Allen's ability to handle complex problems. It also demonstrates his keen desire, successful in this case, to seek a physical understanding of the phenomena. These papers were widely studied and Allen derived considerable pleasure in later years when reminded by metallurgists of his pioneering contributions in this field of metallurgy.

During this investigation, Allen experienced his first contacts with industry since many of the specimens he examined were produced commercially in the works of the firms supporting the research. It appears that he had succeeded in impressing the industrial members of the Association with the practical

application of his work since it was at the 'urgent request of the copper manufacturers that his appointment was renewed' in 1927.

In consequence of this work, Allen was awarded the D.Sc. degree by Birmingham University in 1934.

PERIOD AT THE MOND NICKEL RESEARCH LABORATORIES

Allen resigned from his post as lecturer in March 1933, to join the Mond Nickel Research Laboratory in Birmingham where he remained until 1945 when he left to take up the appointment of Superintendent of the Metallurgy Division at the National Physical Laboratory.

The history and activities of the Mond Nickel Laboratory are described by Dr Allen himself in his obituary notice of Dr L. B. Pfeil (1) who was the head of the Laboratories during this period. Allen and Pfeil had no doubt generated mutual respect for each other at Swansea when they worked together under Professor Edwards. New Mond Nickel laboratories were built in 1934–36, the activities and facilities were rapidly expanded and the organization quickly established itself as one of the principal metallurgical research establishments in the country. Its essential function was to develop additional uses for nickel and thus expand the demand for the metal.

Allen was second in command to Dr Pfeil and, apart from his overall administrative duties covering the research programme as a whole, was concerned with two major research projects, one dealing with the transformation characteristics of low alloy content constructional steels and the other from 1939 onwards the development of highly alloyed nickel base materials having high strength and high oxidation resistance at elevated temperatures.

Allen's method of handling the administration was as follows. First, all the graduate members of the staff met for morning tea around the same bench in the laboratory when he could become *au fait* with the situation on any research item. Secondly, for every agreed programme of work there was a progress card. At intervals of two to three weeks, he appeared with the appropriate card to discuss progress since the previous meeting. The next stages were agreed together with a timetable. When the agreed time was up, he appeared regularly with the card and if the agreed programme had not been adhered to, 'the inquest was lengthy and severe'. Allen insisted that reports of investigations must conform to high standards both in regard to logical arrangement and literary style. Sometimes reports passed through several drafts before an acceptable standard was achieved. Naturally, some members found this irritating but others learnt to appreciate the discipline, realizing that it led to an improvement in the quality of the work of the laboratory. The progressing system is interesting since some such system is desirable in dealing with the many *ad hoc* industrial problems which arise from time to time, the solution of which is essential to enable manufacture to proceed.

To the two main subjects of research in which Allen was personally involved, he made noteworthy contributions. The work on transformations coincided in time with similar work in other parts of the world. For very many years the

behaviour of alloy steels during the hardening operation had been deduced from considerations of the evolution of heat during the change from austenite to the various low temperature decomposition products subsequently examined and identified at room temperature. These methods were unsatisfactory since the experimental results were very difficult to interpret and were in any case markedly affected by the cooling rates used. Davenport and Bain developed the so-called isothermal technique in which a number of specimens were cooled very rapidly to a chosen constant temperature from the hardening range and the structure was examined as a function of the time elapsed by removing specimens after different time intervals. The rate of transformation at this temperature could then be assessed. The chosen temperature was then varied and the experiments repeated.

The method used by Allen and his collaborators was based on the fact that the change from austenite (face-centred) to ferrite (body-centred) iron is accompanied by an expansion and this expansion is proportional, after certain refinements, to the extent of the transformation. The specimen after austenitizing was plunged in a liquid bath held at a fixed temperature and its length measured in a dilatometer as a function of time. He could thus obtain the information for each given temperature from one experiment and this provided a very convenient method so long as the transformation did not take too long or was too rapid. However, in contrast to the Davenport and Bain method, it gave no first-hand information on the type of decomposition products.

For any given composition of steel, a certain critical rate of cooling must be exceeded if the decomposition products ferrite and pearlite, which are undesirable for optimum physical properties, are to be avoided. As the cross-section of the steel increases, the cooling rate in the centre of the piece for any given quenching process diminishes. In practical terms this means that plain carbon steels cannot be properly 'through' hardened except in very small sections. The addition of alloying elements such as nickel, chromium, etc. reduces the critical cooling rate and thus enables larger diameter sections to be hardened properly. These additions, however, increase the cost; they also lead to increased requirements for alloying elements, and in particular nickel, which were in very short supply during the second World War.

A detailed knowledge, therefore, of the effect of alloying elements enabled the maximum economy in use of these strategic elements to be effected during the war and has led subsequently to the development of appropriate compositions at minimum alloying cost for the greatly expanded vehicle industries. Allen would comment from time to time in later years on the curious fact that a Laboratory built to expand the uses of nickel should have worked so effectively to lead to economy in its use.

The development of the Nimonic series of alloys is described at some length by Allen (1) and is a fascinating story.

Before the 1939 war, a good deal of feasibility work had been carried out by engineers on the possibility of developing the gas turbine as a producer of power. In order to obtain efficiencies comparable with the steam turbine, materials were

required with high temperature properties significantly better than those available at the time. The advent of the Whittle engine directed much increased attention to the problem and in one important way simplified it—it was estimated that 300 hours would cover the life of an aircraft engine at maximum stress. This was a period much shorter than that envisaged for normal turbines and permitted laboratory creep tests to be made covering the whole expected life of the material.

The Nimonic alloys as originally developed consisted essentially of nickel and chromium with small amounts of aluminium and titanium. The exceptional properties were developed by careful control of a precipitation hardening process which relies on the decreasing solubility with temperature of complex compounds containing titanium and aluminium. The importance of this work is quite outstanding for without the Nimonic products the Whittle engine would have remained an interesting possibility for a considerably longer period. Subsequently, the range of alloys has been expanded and the properties still further improved. In spite of the quite phenomenal effort put into this phase of metallurgical research by the Americans from 1946 up to and including the Korean war, the nickel alloys developed in the United Kingdom remain the standard blading material for many aircraft and land-based gas turbine installations throughout the world.

Allen refers to the 'enormous amount of development work' involved. This not only covered the laboratory work on the many permutations of chemical compositions and heat treatment but also the works developments necessary to enable a laboratory sample to be reproduced commercially and supplied in quantities and sections to a reliable delivery schedule. On this class of material the laboratory development and the works development are equally formidable and there can be no doubt that Allen's faculty for precise and detailed planning and his knowledge of industrial affairs made a major contribution to the speed with which the whole project became available for exploitation by the engine designers.

NATIONAL PHYSICAL LABORATORY

It will be clear from the preceding history that Allen's experience made him a particularly suitable choice as Superintendent of the Metallurgy Division of the National Physical Laboratory. Although he had an academic background, he had by this time a wide knowledge of both non-ferrous and ferrous industrial problems. He had been concerned as a principal with three major metallurgical developments and had considerable administrative experience in operating a metallurgical laboratory. His standards were in keeping with the high standards of the Laboratory.

He joined the Laboratory at an interesting time. During the war, most of the pre-war research programmes of the Division had been abandoned and replaced either by *ad hoc* investigations required by the Services or by programmes concerned with the ballistic properties of armour plate and shell. This work either ceased at the end of the war or was moved into the Armament Research

Establishments. A number of the senior staff of the Division were at or near retiring age.

Allen therefore had the opportunity to assess the various long-term programmes of the Metallurgy Division and to reorientate them in the light of the many new metallurgical problems and ideas which had arisen during the war period. He inherited a major restaffing problem which presented particular difficulties in the immediate post-war period. He succeeded in collecting around him a talented staff suited to the various new programmes he undertook.

Allen was to stay at the N.P.L. until his retirement in 1969: during this period both the scientific staff and the floor space available in the Division doubled.

The scope of the metallurgical work at the N.P.L. is extensive and Allen's published papers deal with only those projects in which he happened to have a particular interest at the time. He was, however, fully conversant with the whole programme and his energy and insight provided a stimulus which was appreciated by all his colleagues. His policy was to keep a 'good mix' in the programme of the Division covering the range from the academic to the very practical items which industry called for from time to time on a fee basis. These latter projects maintained the Division's contacts with industry and in some cases were quite important—the N.P.L. examination of the Uskmouth turbine failure being a case in point. The following notes refer to projects with which Allen was personally concerned or projects which he introduced and developed through his colleagues.

Work for Government Bodies, etc.

The various Government Ministries consult the Division on metallurgical problems before deciding on the policy to be adopted on the many developments of an engineering character with which they are concerned. In particular, the D.S.I.R. and its successors use it to advise on the timeliness and promise of the many research and development projects they are asked or advised to support from time to time. The Division thus has an up to date picture of much of the R. & D. on metallurgical and allied work which is financed from Government sources.

In 1963, the D.S.I.R. initiated the 'superconductivity project' largely owing to the energy and inspiration of Allen who was keen to see the uses of superconductors developed in industry. The project had three main objectives: to ensure that U.K. manufacturers would be able to make the necessary material; to enable industry to develop the expertise to use the material; and to provide an adequate research background. Allen was Chairman of the advisory committee which ran the whole project from 1963 to 1971; this committee consisted of representatives from industry, Government and the universities. He was also Chairman of the Specialist Panel from 1963, set up to coordinate research in superconducting materials for superconducting magnets.

The project attained its original objectives—superconducting material is now available in quantity from British sources and has been used in a number of interesting devices, e.g. the quadruple magnet for focusing the proton beam

of the 28 GeV proton synchrotron at C.E.R.N. in Geneva, and the homo polar 2400 kW 200 rev/min motor constructed by the International Research and Development Company Ltd. This latter machine contains 5.33 tons of superconductor.

In certain cases specific research programmes were undertaken, as, for example, immediately after the war when the Division worked on the properties of uranium and beryllium for the Atomic Energy Authority while it was building up its own facilities at Harwell and Risley.

From 1962 to 1969, Allen was Chairman of the Inter-Services Metallurgical Research Council.

In addition, the Division has certain continuing commitments concerning the safety of such items as gas cylinders, pressure vessels, chains, lifting gear, etc.

In the early part of the last war, a number of high tensile steel cylinders burst in service—some forming part of the Balloon Barrage. Certain decisions regarding the operational conditions were made and further explosions did not occur. After the war, the whole subject was re-examined in the light of the stress corrosion cracking which had been established in the defective cylinders. The investigation was widened to include the use of cylinders, etc. for both low and high pressure liquefiable gases. This provided the N.P.L. with a great deal of work. As a result, the Home Office Gas Cylinders and Containers Committee was able to bring in a comprehensive revision and systemization of its regulations; the basis of design was worked out applicable to all gases; the range of materials acceptable was widened, and the regulations for large welded containers for the transport of low pressure liquefied gases were brought into agreement with those for pressure vessels generally. This work was particularly opportune in view of the great increase in the availability of liquefied petroleum gases which has taken place since the war.

Development of materials for high temperature service

The N.P.L. has been concerned with the creep of metals since the phenomenon was first appreciated. In 1929, the British Electrical and Allied Industries Research Association set up a committee, the J/E. Committee, to foster work on this subject in connection with power stations, and has continued to sponsor work of which the major part of the experimental work has been carried out at the N.P.L.; the Engineering Division and subsequently the Mechanical Engineering Research Laboratories handled the actual creep measurements—the Metallurgy Division examined the changes in structure in order to arrive at an explanation of the observed phenomena. While the long-term creep tests were continued during the war, very little time was available for other work and many items in the programme were left in abeyance. Peacetime brought renewed interest in this subject particularly as the power station programme led to the need for increased steam operating temperatures and a large increase in size of the individual operating units.

Allen was appointed a member of the main J/E. Committee in 1944 and was its Chairman from 1953 to 1960. He was a member of the sectional committee

on Power Plant from 1953 to 1960, of the Research Advisory Committee on Steels for High Temperatures from 1961 to 1967, and of the Sub-Committee on Titanium Alloys from 1956 to 1960.

A good deal of the actual testing work on the Nimonic alloys during the war was carried out at the N.P.L. Subsequent to the war, further work associated with similar materials suitable for use in the industrial gas turbine was incorporated into the overall creep programme.

An examination of specimens cut from typical components of power station equipment—superheater tubes, turbines, blades and steam pipes—revealed many significant anomalies where materials of the same composition with identical room temperature properties behaved quite differently at elevated temperatures. The reasons for many of these anomalies were worked out; the effect of different deoxidizing techniques on steam piping materials, the effect of variation in normalizing treatments on the rate of creep and on the maximum elongation in creep before intercrystalline cracking occurred. The behaviour under creep of materials as a function of the prevailing atmosphere—steam, hydrogen, flue gases, etc.—was examined. The effects of the steps in the different tube making processes were systematically examined and enabled satisfactory tubes to be made by all processes.

When between 1956 and 1960 the main creep laboratory facilities were transferred to East Kilbride and additional equipment was installed by the Electrical Research Association, a residue of creep testing facilities was retained in the Metallurgy Division and the Division maintained its special interest in the metallurgical problems arising out of the work. A study was made of the dislocation patterns of pure iron, some of its alloys, and actual power station materials when under creep.

There can be no doubt that the contribution made by the N.P.L. during Allen's period of office to the understanding of the behaviour of metals when stressed at elevated temperatures enabled the turbine designers with confidence to continually increase the size and operating temperature of the turbine units with a material improvement in operating efficiency. The results arising from this work were eagerly absorbed by foreign designers since they appreciated both their accuracy and their objectivity.

Exploratory work was carried out on the newer metals, titanium, chromium, zirconium, niobium, with a view to assessing their possibilities in high temperature applications. This was supplemented by an examination of the creep properties of commercially available titanium alloys as affected by dissolved hydrogen. The niobium investigation, amusingly enough, led to the examination of niobium alloys as a basis for superconducting alloys; that on chromium to the present interest in dispersion strengthened chromium.

Development and improvement of techniques

One of the essential functions of the N.P.L. is to provide continuously improving methods of measurement and examination. This was a task much to Allen's liking.

The Division, in collaboration with the British Iron and Steel Research Association, developed chemical techniques for the determination of trace elements in pure iron, which were measured in parts per million.

Physical methods of analysis—spectrographic analysis, chromatography, colorimetry, X-ray fluorescence, absorption spectrometry—were improved. Mass spectrometry was applied to metallurgical analysis and as a check on the other methods of analysis. The study of soft X-ray spectra was developed to give information on the condition of valence electrons in alloys.

Allen himself was particularly concerned with the development of the electron microscope for the examination of metallurgical structures. The Division was one of the first laboratories to use the instrument—in 1942, but since the replica techniques were then used its information was distrusted. By comparing its images with those given by a reflecting phase-contrast optical microscope, the reliability was improved and useful information was established on the precipitation of small amounts of carbide from freshly quenched martensite and very dilute solutions of carbon in iron.

In 1949, when discussing metallurgical problems awaiting solution, Allen said 'the "dislocations" that present themselves so vividly to the younger generation of metallurgists are unfortunately too small to be seen'. When in 1957 the examination of thin metal films became possible, dislocations could be shown directly and the Division took up the application of the method to iron and its alloys energetically. The dislocation structures in iron were examined to determine their relation to the mechanical properties of the material.

In all this work, the thinness of the sample under examination introduced limitations; with such a small volume the material might not be representative and it was desirable to study movements while the stress was being applied. The potentialities of a high voltage microscope were considered, and in 1965 the construction of a 1 MV apparatus was decided upon. The first photographs on this machine were taken in 1970.

Constitutional work

The laboratory has always been a centre for the accurate determination of equilibrium diagrams. New problems were selected by Allen for the postwar programme which were likely to provide more precise constitutional data relating to other researches going on in the laboratory. The studies of the FeMnO and FeSiO systems were of use in the investigations into the properties of slightly alloyed pure iron for example; and the diagrams for FeTiO, TiAl, TiV and TiMo in relation to the development of alloys of titanium which was beginning to become available in commercial quantities. The studies of the σ phase of the chromium iron system were extended to cover the nickel chromium iron system and the rates of transformation from the γ to α phase in pure iron nickel and iron manganese alloys examined.

Allen was interested in deriving equilibrium diagrams from first principles using thermal data—heats of formation, free energies, etc., and he set up a new

section specifically to do this. The methods of measurement available for the determination of the data were critically reviewed and the existing information collected, examined and published in book form (2, 3). In addition, experimental work was carried out on a number of systems, particularly the iron nickel and iron chromium, to supplement and check existing data.

In the case of the iron chromium system, calculation of the phase boundaries in the solid state agreed very well with the boundaries experimentally determined by the orthodox manner at temperatures where diffusion is reasonably fast. At lower temperatures the thermodynamic data predicted that the σ phase should undergo a decomposition into chromium and iron around 500 °C. In the case of chromium molybdenum alloys which were thought to consist of a range of solid solutions, it was predicted and confirmed that decomposition would occur well below the melting point.

At the service temperature of many commercial alloys, the rate of diffusion is very slow; even so, since the length of service may be 100 000 hours or more, significant changes in constitution can occur if the material is in metastable equilibrium. The use of thermodynamic data of adequate accuracy enables valuable predictions to be made of the likely long-term behaviour.

Alloys of iron

Before the 1939–45 war, the N.P.L. had carried out an extensive programme of work for the British Iron and Steel Federation on alloys of iron. Much of this was concerned with the establishment of accurate equilibrium diagrams. During the war, the necessity to conserve alloying elements had led to the view that any combination of alloy additions which gave a given hardness should be equally satisfactory although this contradicted the traditionally held view of the special suitability of certain well-tried combinations. The catastrophic break-up of certain welded ships constructed from mild steel under apparently quite low stresses directed urgent attention to the problem of brittle fracture in material which under normal circumstances failed in a ductile manner.

In 1946, the Laboratory began a long-term investigation in collaboration with B.I.S.R.A. to determine the effect of alloying elements upon the mechanical properties of pure iron in an attempt to distinguish between their effects on the properties of the iron crystal and their effects upon the complex structures in steel arising from heat treatment.

Techniques had been developed for the production of really high purity iron in relatively small quantities necessary for the pre-war constitutional work. Equipment was developed using vacuum melting procedures whereby iron of the required purity could be produced on a 20 kg scale. This enabled test pieces of adequate size to be used in the testing programme for mechanical properties and also enabled supplies of iron to be made available to other laboratories working on the subject.

It is not easy to summarize the very large amount of work which was carried out on this project during Allen's period partly because it is so extensive and partly because certain phenomena still remain unexplained.

However, definite progress was achieved in this highly complex problem. The work showed that the transition from tough to brittle fracture was extremely abrupt in pure iron and took place at a higher temperature when notches were present. The major steel-making alloys did affect the transition temperature but not to any marked extent, their role in alloy steels is primarily to control the transformation rates and thus permit adequate hardening in large cross-sections. Strikingly injurious effects, however, were produced by small amounts of non-metallic elements—oxygen, nitrogen, phosphorus—and on to these effects had to be superimposed the effects of grain size and heat treatment. The effect of carbon on pure iron was quite marked—the addition of 0.05% gave a material which after quenching from the austenitizing temperature had a high strength and which retained its toughness to quite low temperatures.

From 1952 onwards, B.I.S.R.A. made many experiments to turn these findings to practical account. The introduction of oxygen steel making in recent years with improved process control has enabled the purity of 'commercial' iron to be increased. Simultaneously, additions of small amounts of niobium which are used in conjunction with controlled rolling ensured a recrystallized austenite which on accelerated cooling gave a very fine grained structure. As a result, much improved mild steels are becoming available for structural purposes.

While this work was going on, detailed studies of the fracture properties of single crystals of iron were made at temperatures down to that of liquid helium. It was shown that the crystal fails in a ductile manner, irrespective of the orientation of the crystal to the direction of the applied tensile stress, down to quite a low temperature, -124°C : at liquid air temperatures cleavage may take place depending in a complex manner on the orientation, and at liquid helium temperatures the fracture is a cleavage one irrespective of the orientation.

The severe embrittlement produced by P, O₂, N₂ in polycrystalline materials was not reproduced in single crystals indicating that the effects of these elements were primarily concerned with grain boundary conditions.

All this work contributed to the considerations which led to the wide interest in improving steel making procedures in the late 1950s and to the rapid changes which are now taking place in the plant actually used for steel making—LD process—and large-scale vacuum melting and electroslog melting installations.

GENERAL

In 1966 Allen was appointed Deputy Director of the N.P.L. and until he retired in 1969 he was concerned with the administrative changes needed in the formation of a Materials Group which absorbed his old Division.

As has been indicated earlier, Allen was a very hard worker and particularly conscientious. His standards were high and he did not disguise the fact that he found it difficult to tolerate anything slipshod either in experimental work or by way of argument.

He was particularly good at stating a case, and there can be little doubt that he enjoyed an argument. As he seldom joined a debate unless he was fully

informed and convinced, he was a formidable opponent. Some of his less well-prepared antagonists reacted rather unfavourably to the treatment they received. As he became more involved in committee work and particularly in later years when he functioned so often as Chairman, he mellowed noticeably. While he enjoyed attending scientific meetings and conferences, he did not enjoy, and often avoided, the social functions which accompany them.

He travelled widely, usually by invitation, and gave numerous lectures abroad. He enjoyed this since it permitted him to keep abreast of ideas and experimental techniques throughout the world.

Allen spent much time and effort in promoting the welfare of others, usually quite unbeknown to the individuals concerned. Cases for promotion and the many recommendations he had to make in connexion with appointments outside the Division were prepared with great care to ensure that full and proper credit was given to the person concerned.

He kept up his interest in the younger generation of metallurgists and he was elected an Honorary Member by both the Birmingham and Sheffield Metallurgical Societies. He acted as an Assessor for the Universities Grants Committee on the various expansion schemes for metallurgical departments which took place in the 1960s. Here his detailed knowledge of the needs and the equipment necessary for both postgraduate research and undergraduate training made him particularly useful.

He received many Honours:

Lightfoot Medal, Institute of Refrigeration	1954
Fellow of The Royal Society	1956
Hatfield Memorial Lecture, The Iron and Steel Institute	1958
President, The Institution of Metallurgists	1961–62
Osmond Medal, Société Française de Metallurgie	1963
Hon. Doctorate Technical Science, University of Prague	1964
Bessemer Medal, The Iron and Steel Institute	1965
Hon. Doctorate Metallurgy, Sheffield University	1966
Companion of the Order of the Bath	1966
Platinum Medal, The Institute of Metals	1967
Hon. Vice-President, The Iron and Steel Institute	1968
Luizi Losana Gold Medal, Associazione Italiana di Metallurgia	1968
Hon. Fellowship of The Institute of Metals	1971

Fortunately, Allen could relax easily. In the middle of a conference, he could become thoroughly immersed in a visit to an old building—a reminder of his early archaeological interests. At home, he took a full interest in his family and their development. Round about 1955, when walking in the Welsh hills, he had the first warnings that his heart was defective and that his walking had to be less strenuous. He was also advised to take things more easily as far as his work was concerned. He enjoyed gardening and in his later years took up painting. He was most enthusiastic about this and would put in spells of about two hours' duration whenever he could find the time. His paintings are very presentable, readily recognizable and gave him considerable pleasure.

He found the changes on retirement not to his liking; he missed the daily contact with metallurgical developments. After retirement, he carried on some of his committee work, notably the superconductivity project, and some minor consulting work.

He had two sons, one trained as an aeronautical engineer, the other as an optician, and one daughter married to a soil scientist.

Allen died suddenly on 23 February 1972, when influenza brought on failure of an already weakened heart.

Allen's career spanned a period during which real progress was achieved in the development of an improved physical understanding of many important metallurgical problems. In three of these fields—casting of non-ferrous alloys, Nimonic alloys and mechanical properties of iron and its alloys—Allen's contribution was outstanding—and to this must be added the benefits his stimulus and insight brought to metallurgical progress as a whole.

My thanks are due to many people who have helped in providing information for this Notice, and I would particularly mention Dr Allen's wife, his son Peter, his sister Lady Cook, Dr A. H. Sully; Mr C. W. Tod, a life-long friend; and Dr J. A. Catterall and Dr D. McLean, his colleagues at the N.P.L.

The photograph is by R. Eric Smale, Kingston on Thames.

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