Institute of Railway Studies

Working papers in railway studies, number eight

British railway research – the first hundred years

Text by the late Sam Wise

Edited by A. O. Gilchrist and with a biographical note by E. S. Burdon

Published by

Institute of Railway Studies

National Railway Museum
Leeman Road
York YO26 4XJ
UK

University of York
Heslington
York YO10 5DD
UK

ISSN 1368-0706

British Railway Research – The First Hundred Years

TEXT BY THE LATE S.WISE, C. ENG., F.I.MECH.E.,M.I.M.

EDITED FOR THE INSTITUTE OF RAILWAY STUDIES BY A.O.GILCHRIST, AND WITH A BIOGRAPHICAL NOTE BY E.S.BURDON.

Contents

Preface

ALASTAIR GILCHRIST

Following his retirement, Sam Wise undertook a labour of love: the writing of the history of railway research in Britain. Unhappily he did not live to complete his self-appointed task. However, Sid Burdon, his professional colleague and a family friend, has recovered for us the surviving typescript and word-processor discs, and these show that Sam had largely completed his work to 1960, and was drafting the chapter that brings the story to about 1964. In preparing this material for publication I have tried to preserve all of Sam's finished, or nearly finished, text. I was anxious to do this as the earlier period is well researched and reliable; it also benefited from information and advice from colleagues no longer alive. The later sections have the colour and authority of a narrative written at first hand.

In editing the text I have made a large number of small corrections of the sort that Sam himself would have found necessary: removing duplications, clarifying constructions and making links. This included reversing the sequence of the original Chapters 4 and 5. In Chapter 2 I have added a few paragraphs to record the continuity of research effort, mainly in chemistry, on the Great Western and London and North Eastern Railways; thanks to Eric Henley's advice, more detail is possible in the LNER case. Then in later chapters I have supplied the text describing the LMS Physics Section that was missing from Chapter 8, being helped in this by Leslie Thyer, Roy Bickerstaffe and Douglas Wright. From Chapter 10 onwards I have added several paragraphs to strengthen the description of activities in subjects other than Engineering. I have also clarified the organisational background, a task which was made much easier for me by the availability of Dr. Gourvish's book "British Railways 1948-1973". Chapter 13 is basically my own composition, but includes substantial elements from "rough notes" left by Sam, for example relating to the Western Region's Soil Mechanics Laboratory, the strengthening of project control in the Engineering Division and the opening of the new Engineering Laboratories. Finally I have added a Postscript in my own name summarising the situation already described and sketching very briefly the subsequent history of British Railways Research Department up to its sale under the Privatisation initiative in 1996.

I have checked numerous facts throughout the text against primary sources held in Derby, at the BRB Record Centre in Paddington, at the Public Record Office in Kew and at the Institution of Mechanical Engineers. I have also been aided by many helpful telephone conversations with colleagues. Sam did not leave a record of his sources; however I have added an Appendix listing relevant documents that I am aware of and have used in my checking of the text. When certain of my ground, I have altered the text accordingly. Of course some errors may remain, but I hope they are relatively few.

Derby, January 2000.

Biographical Note: Sidney Wise 1917-1992

SID BURDON

"Sam", as he always preferred to be known, was born in London on 1 August 1917 and attended the Dulwich Hamlet London County Council School. From there he won a Junior County Scholarship in 1928, which took him to Sloane School for the next five years. On matriculating at the end of this period, he moved to the Crewe Locomotive Works of the then London Midland and Scottish Railway as an engineering apprentice where he did the usual round, gathering experience in the various workshops undertaking the building and repair of steam locomotives.

Between the years 1933-1938 he also acquired both Ordinary National Certificate and Higher National Certificate in Mechanical Engineering, studying at Crewe Technical College and Manchester College of Technology, before taking up an appointment as assistant to the Works Engineer at Crewe for three years and then as Assistant Works Metallurgist, LMS, at Crewe between 1941 and 1944. At the same time he was again studying at night school, this time diversifying into welding and metallurgy and acquiring City and Guilds Certificates.

In 1944 he made the move to Ashford as Assistant Head of the Physical Laboratory, Mechanical Engineering Research Department, Southern Railway, where he was involved in a wide range of work including developments in non-destructive testing and experimental stress analysis, which both featured to a considerable extent in his later work. The LMS and Southern Railway Research Departments were combined in 1951 at which point Sam became Senior Engineering Assistant, BR Research Department, Ashford, for two years before moving to Derby as Senior Scientific Officer and then Senior Principal Scientific Officer in charge of the Strength of Materials Group up until 1961.

As Assistant Director (Mechanical) of the Engineering Division of British Railways' Research Department from 1961 to 1972 Sam was responsible for a wide range of activities including, at different times, Strength of Materials, Structures, Metallurgy, Non-destructive Testing, Instrumentation, Drawing Office, etc.

Between 1972 and 1982 Sam was Materials and Inspection Engineer and later Quality Assurance Manger, British Rail, in the Director of Mechanical and Electrical Engineer's Department where he oversaw the transition from traditional methods of Inspection to Suppliers' Quality Assurance.

After retirement in 1982, he acted as a Senior Mechanical Engineering Consultant on behalf of Transmark.

As a Fellow of the Institution of Mechanical Engineers, Sam was very active in Railway Division affairs as evidenced by his winning the George Stephenson Prize for papers in 1960, 1970 and 1973. He was a Fellow of the Institution of Non-destructive Testing and a Member of the Institution of Metallurgists. During his retirement Sam continued his involvement with all three institutions and at the same time commenced writing his book on the history of Railway Research in the UK. After his death in November 1992 it was decided that the book as far as he had completed it, was much too valuable as a source document to lose. As a mark of respect to a dedicated Railway Engineer, his work has been collated and edited by colleagues and is published in this monograph.

Chapter 1: In the Beginning – Applied Chemistry

Research is now a widely used word, perhaps over-used, and frequently associated with preparatory work for certain types of television programme and in the presentation by Public Relations men of new products or services. This type of research involves the study of historic facts in existence, but perhaps buried in rarely consulted books or statistical records. The other kind of research, called scientific, is more concerned with acquiring knowledge and understanding of natural phenomena and the physics, chemistry and mechanics of life, of natural substances and man-made objects and mechanisms. Most major industrial organisations in the Western world probably possess "scientific" research laboratories; the use of research of this type is both expected and taken for granted these days.

No one therefore will feel surprised to learn that the railways of Britain have formal research facilities, but many may be surprised at the length of time these facilities have been in existence. British Railways' Research Department was formed in 1951, but this was preceded by the LMS Scientific Research Department, established as early as 1933. Did this creation of Sir Josiah Stamp and Sir Harold Hartley mark the true commencement of the application of scientific knowledge and methods to railway problems? Some of the early history is now difficult to perceive through the mists of time, but it can be established that the date of the beginning of scientific work was 1864 and that the place was Crewe, or more precisely Crewe Works.

At the tiny hamlet of Crewe (or Monks Coppenhall) the London & North Western Railway (and its predecessors) had built a railway centre with a station, an important junction and a locomotive construction and repair works. It had also built a town of about 20,000 people and supplied the townsfolk with both gas and water. The Works and the Locomotive running shed also made great demands for water, with the result that the supply was unsatisfactory both in quantity and in quality, so much so that there were embarrassing outbreaks of cholera from time to time. Twenty-five miles away at Chester there was a theological college which also had some scientific leanings and which carried out water analysis for the LNWR on occasions although this was not considered satisfactory as a permanent arrangement. Moreover, in addition to the water problem, a major new factor had just arrived – steel. Crewe Works always liked to be self-sufficient and had made its own iron castings and wrought iron for years. Wrought iron was used for plates for boilers and frames and for axle and motion forgings but it was far from ideal. Although ductile it was also soft and made only in small and somewhat variable lots of about 250kg. In 1855/6 Henry Bessemer patented his process for making steel by blowing air through liquid iron in a converter; his first plant came into operation a few years later. J. Ramsbottom, the Locomotive Superintendent of the LNWR and "man-in-charge" at Crewe, seeing the potential of the new process persuaded the Board to take out a licence to construct a Bessemer plant at Crewe which was first "blown" in 1864. Bessemer steel-making was a much faster process and produced steel in 5 tonne batches. The product was also harder and stronger and its composition could be varied within limits as required. Unlike wrought iron, whose quality was assessed by looking at the fracture of a sample, it was desirable to take some account of the chemical composition of steel, particularly of the deleterious elements sulphur and phosphorus whose presence persisted from the iron ore smelted to make the pig iron from which the steel was refined. It was clear to Ramsbottom that what he needed was chemical analysis of water and of Bessemer steel output (and the raw material) performed at Crewe. The net result was the appointment in 1864 of Mr E Swann, a one-time student of Chester College, as an analytical chemist at a salary of £2 per week. Thus the use of applied science on the railways began.

Swann was put to work in a hut in the works; his primary duties were in connection with the Bessemer plant, but he was soon involved in the analysis of other things, particularly oil, coal, coke, paint and non-ferrous metals. Water continued also to be an important problem especially when there were further outbreaks of cholera due to inadequate sewers. After one year Swann was given an assistant because of the volume of work, but in 1867 Swann left the railway and his name disappears from the records. He was succeeded by another Chester College student, John Dods, and the laboratory moved to slightly better premises at the “Deviation”, now Eaton Street.

The second Crewe chemist Dods also left after three years and was succeeded by his assistant Joseph Reddrop, who had been apprenticed at Crewe and who had also managed to take a course at the Royal School of Mines. Under the influence of the Locomotive Superintendent, Francis Webb, the work of the laboratory extended to include analysis of leather, soap, bricks, cement, creosote, lubricating and burning oil and of course coal, coke and gas. Reddrop reigned as Chief Chemist at Crewe for thirty years, although not until 1876 did Webb recommend “....that Mr Reddrop now paid at the rate of 50s. a week be transferred to the salary list at £150 per annum”.

In the field of metal analysis and in others Reddrop made a major contribution to the LNWR; amongst other things he invented a foot warmer for use in unheated third class carriages. It consisted of a container of sodium acetate in the fused condition and depended upon the very high latent heat of solidification of the substance which thus gave out heat for a long time as the contents solidified. He soon had a staff of eight assistants and the laboratory was moved again to more commodious premises. The 1884/5 accounts showed that 1000 carbon estimations on Bessemer steel had been made, together with 400 analyses of miscellaneous alloys and materials. Work was also being done for the Depots at Camden, Edge Hill and Willesden, while interest was now being taken in the control of water softening procedures. Reddrop’s reputation spread beyond the railways; he became one of the earliest Fellows of the Institute of Chemistry in 1878 and an original member of the Society for Chemical Industry, founded in 1881.

The action taken by the LNWR, and the successes of the chemists at Crewe, did not influence the other major railways immediately. The first to move was the North Eastern Railway, which in 1876 engaged Robert Routledge, a well qualified scientist and also an author and publisher. It was probably in 1877 that the LNWR’s great rival, the Midland, first acted to create a laboratory at Derby. However it was the chemist chosen by Samuel Johnson, the locomotive superintendent, in 1881 that established its reputation. This was Leonard Archbutt who became a major figure among railway chemists and who was to hold office for 40 years. Archbutt was perhaps fortunate in marrying the daughter of the next locomotive superintendent of the Midland, R M Deeley, of Midland Compound fame. Whether it was because of his marriage or as a true reflection of his ability is unknown, but he was paid the extraordinary salary for the time of £1,000 per annum. However, his achievements were many and not all confined to railway chemistry. For example, in 1890 he was co-author of a paper on the Thermodynamics of the Vacuum Brake, then co-inventor with Deeley of a water softening process and joint author (again with Deeley) of a standard text book on Lubrication, first published in 1900. He became a Fellow of the Institute of Chemistry in 1888 and was a distinguished member of both the Society of Chemical Industry and the Institute of Metals.

Meanwhile Reddrop’s assistant at Crewe, F W Harris, left in 1882 to become a chemist-draughtsman at Swindon under William Dean; later one of his assistants at Swindon, John Jenkins, went to Stratford to succeed the man who set up the Great Eastern Railway’s laboratory there. Over the next thirty years, all the principal railways appointed chemists and set up laboratories. By 1915, the process was complete and the situation was as shown in the table below:

Railway Company	**Location of Laboratory**	**Year founded**	**First (or first known) Chemist**
London & North Western Railway	Crewe	1864	E Swann
North Eastern Railway	York, then two locations in Gateshead, then Darlington from 1912	1876	R Routledge BSc
Midland Railway	Derby	1877 or earlier	Day
Great Western Railway	Swindon	1882	F W Harris

Railway Company	Location of Laboratory	Year founded	First (or first known) Chemist
Caledonian Railway	Glasgow St. Rollox	1882 or earlier	S Stewart
Lancashire & Yorkshire Railway	Horwich	1887	C J P Fuller
Manchester Sheffield & Lincolnshire (later Great Central) Railway	Gorton	1888	H Gripper
Great Northern Railway	Doncaster	1886 or earlier	J Macfarlane
Great Eastern Railway	Stratford (East London)	1890	H J Phillips
London & North Western Railway	Wolverton	1890 (?)	H Mennel (from 1908)
North British Railway	Glasgow Cowlairs	1894	Somerville
Great North of Scotland Railway	Inverurie	1897	Urquhart (from 1914)
London & South Western Railway	Wimbledon	1903	E A Dancaster
London Brighton & South Coast Railway	Brighton	1912	F P Matthewman
London & South Western Railway	Nine Elms	1914	Derrington
South Eastern & Chatham Railway	Ashford	1915	H Hall

This impressive list of laboratories shows that all the principal railways at that time agreed on the value of employing chemists as applied scientists; in this period there were over 100 men in the railway laboratories, of whom about half possessed qualifications. What did they all do? The short answer is that they did almost everything they were asked so that they were approaching the state of being all things to all men. But their principal activities fell into five categories spanning a very wide range of railway interests. These were as follows.

1. Metal Analysis and Services to Workshops and Depots

Although only Crewe and Horwich had steelmaking furnaces and steel foundries, virtually all works had iron and brass foundries. Each of these generated a need for the analysis of a large range of purchased raw materials such as pig-iron, copper, tin and zinc, as well as non-metallic materials consumed in foundries and forges: firebricks, fire clay and other refractory substances, moulding sands, core sands, coke and the ferro-alloys used to adjust compositions in the melt, or as de-oxidisers. Not all of these materials were subjected to full analysis by any means; in most cases experience had taught that perhaps only one impurity or one constituent, for example clay content of moulding sand, was of real importance. Nor was analysis the only operation. For some of these substances other physical properties were of greater importance, such as density, particle size or softening temperatures etc.; whatever scientific test was required it was all grist to the chemist’s mill.

At works without steelworking facilities, all the steel plate, bars, blooms and forgings essential for the construction and repair of locomotives, carriages and wagons had to be purchased from external suppliers. In practice most companies sent inspectors to assess the quality of the material to be supplied and to witness the required tests. Having done this they took samples to send back to base so that the chemists could make check tests. This procedure arose because:

a) The railways wielded tremendous purchasing power since in aggregate they formed the largest manufacturing organisation in the country at that time.
b) There was a fairly low level of appreciation in the steelmaking and allied industries of the relation between the steelmaking, rolling, forging and casting procedures and their effect on product quality.
c) There was then no nationally agreed system of specifications, such as the present British Standards Institution Specifications, to hold the balance between purchaser and supplier: thus the inspector and the chemist tended to act as the arbiters of acceptable quality.

Where there was steelmaking or steel founding on railway premises, the processes required the continuous attendance of chemists on shift. Crewe eventually had four Siemens open hearth furnaces, together with the furnaces supplying the steel foundry; samples for carbon estimation would then be arriving in the laboratory (a subsidiary steelworks laboratory) every fifteen minutes or so for several hours. In the end a Swedish electromagnetic device capable of near instantaneous reading of carbon content was acquired to alleviate the situation and continued in use for many years.

In most main works gas was produced, by the cracking of gas oil, for carriage lighting and restaurant car cooking. This process was also closely monitored by the chemists.

2. Train Operation

The actual operation of the railway produced other work for the chemist, once again mostly of an analytical nature. Obviously coal and water analyses were required, coal for determination of calorific value and ash content, water for tests to see what came in the water as well as H_2O, e.g. questions of the acidity or alkalinity and dissolved salts which would cause corrosion or obstruction of the boiler. The amount and nature of solids in the water was also a concern since this affected the possibility of foaming in the boiler or of "priming". Drinking water too was a continuing subject for analysis, increasing as restaurant cars became more common. There was moreover a need to control lubricating oil, "burning" oil for use in signal lamps and head and tail lamps, and a wide range of other products such as the gas and footwarmer chemicals already mentioned.

3. Commercial Traffic

The railways at the end of the nineteenth century were in a near monopolistic position in the transport of freight. The Government, recognising the situation, placed some curbs, or consumer protection, in place, firstly by requiring the railways to be "common carriers". This meant that they had to carry any and all of the traffic offered unless it could be classed as dangerous. Secondly the railways had to classify all freight into one of twenty-one categories, set a rate or charge per ton-mile for each of the categories and publish the list of charges. Indeed it was not until the 1950s that this restriction was lifted, long after the monopolistic situation had disappeared.

Railway Goods Managers faced with the problem of classification were no doubt pleased to discover that the man engaged in the analysis of metals in the works could just as easily identify the nature and constituents of almost any substance offered to him. Clearly the Goods Department needed to know what a particular product consisted of, as distinct from what the owner or manufacturer said it was, or what its name was on the market, so that the correct rate could be charged. Another problem was that of different railways putting the same product in different classes and making different rates, a situation that could easily arise and cause trouble with the customers and between railways. The solution to this problem was found in the combined use of the Railway Clearing House (RCH) and the chemists from different railways. The RCH had been established in 1842 and existed primarily to divide between railway companies, in an equitable manner, the revenues received from the transport of goods or passengers whose journeys had started on one railway but had been completed at a station on another, having perhaps traversed the territory of a third or even fourth railway en route, each of which was entitled to a proportion of the fare or charge. It was therefore sensible to use the services and the organisation of the RCH to support a Chief Chemists Committee. New materials offered for transport were then analysed or otherwise identified by the originating railway and reported to the Chemists Committee with a classification proposal which, if agreed, became mandatory for all the members of the RCH.

A natural concomitant of Chemists Committee work within the RCH was that on Dangerous Goods. Railways had the right to refuse to carry dangerous goods if they chose, but this power was clearly limited in practice by commercial pressures. Following some serious accidents involving fire the Government required that there should be a Dangerous Goods Committee, which was duly formed as a sub-committee of the Chemists Committee. The chemists engaged in Dangerous Goods work had to analyse the material, or, if its composition was known, to identify the hazards associated with its transport or storage, and to lay down the rules and conditions of acceptance. In particular they would prepare requirements for types of containers and protective packaging, and for safe handling and storage in transit or at stations. For some materials it would also be essential to specify the type of wagon to be used and perhaps the position of the wagon in the train with respect to other vulnerable consignments and to the potentially fire and spark emitting engine.

It will be clear that one result of this involvement of the chemists with the commercial activities of railways was a considerable increase in personal responsibility for Chief Chemists and for laboratory staff of each railway. In particular the chemists working on dangerous goods found their professional duties far removed from the simple routine analysis of substances in the laboratory. The status of Chief Chemists was also greatly enhanced by this involvement with the revenue side of railways, and by the recognition of the value of their services.

4. Claims

A further connection between chemists and Commercial Departments arose through the problem of damaged goods. As a standard practice small consignments were dealt with as “Sundries” in which a number of items consigned to the same station would be loaded in the same wagon, which then trundled through sorting sidings and marshalling yards until its destination was reached. If the contents of the wagon had not been carefully stowed and restrained, or if the wagon had experienced rough shunting during its peregrinations, it was likely that on arrival the contents would be found to be closely intermingled. Items like furniture might be broken or containers split and their contents mixed. Sometimes the most unlikely items were loaded into open wagons which set off unsheeted or which lost the sheet en route, resulting in the wagons contents being soaked by rain during an adventitious storm. Claims from disgruntled consignees led either to a visit by an inspector from the Goods Department, dealing with the physical damage aspect, or by a chemist in cases of contamination of one item, perhaps foodstuff, by spilt acid, oil, cleaning materials or creosote for example. In these cases the chemist had to decide whether the material in question was ruined beyond reclamation, or had suffered only partial damage so that by sorting a proportion could still be satisfactorily used. Claims, always of course for total loss, could therefore frequently be scaled down, with perhaps considerable savings for the railway. Chemists often acquired a good reputation for integrity in their dealings with customers on these occasions; equally it was not unknown for them to investigate a claim and to dismiss it as completely baseless and fraudulent. Diluted whisky from Ireland is an example which leaps to mind.

5. Forensic Work

In this account of chemical laboratory assistance to the commercial departments mention must be made of the work of a forensic nature often undertaken to assist the Railway Police. This included such things as positive identification of stolen railway property or the comparison of printing inks in cases of suspected fraudulent production or alteration of tickets and other documents.

Finally, to complete the answer to the question "what did the chemists do?" it is necessary to refer to miscellaneous activities and to one too important to describe in that manner, the problem of paint. Miscellaneous activities were many and included such things as the interest in photography shown by Francis Tipler who succeeded Reddrop at Crewe in 1899. He became involved in photography to the extent that he was producing publicity photographs of many of the places served by the LNWR as well as records of special activities within Crewe Works – so much so that Bowen-Cooke, when Chief Mechanical Engineer from 1909, addressed memos to him at the Photographic Laboratory. Tipler also advised the railway doctor at Crewe on the installation of a diagnostic X-ray in the railway hospital and investigated unpleasant smells in a hotel dining room. Other chemists calibrated pyrometers, advised on manufacture of fusible plugs, controlled the working of producer gas plants and specified the making of cleaning solutions for rolling stock. Chemists were no longer restricted to the practice of chemistry but concerned themselves also with relevant aspects of heat, light and sound, and to a variable degree with metallurgy. Starting from almost nothing in the applied sciences the railway chemists had by 1914 constructed a very considerable edifice of scientific and technical work to assist the operation of the railways; almost everything achieved was due to the personal initiatives of the various Chief Chemists in response to appeals for help.

Paint however was rather different. It was a "chemical" in which different constituents served different purposes; every constituent was a subject for study and investigation in order to achieve, on locomotives, rolling stock, stations and bridges, paint of the right colour (exactly the right colour for locomotives and coaches) which was economical to apply, long lasting, hardened quickly, was resistant to weather, smoke and cleaning solutions and was also, of course, cheap. Chemists have always specialised in the study of paint and its application and cleaning. In the pre-grouping days every laboratory would have on the roof or near by paint test exposure panels of different colours oriented at 45 degrees to the heavens. In the commercial development of paints for use on the railway it is questionable whether the key figure has been the paint manufacturer or the railway chemist, a situation which continued for many years.

But were the chemists engaged in "research"? Generally they were not. The great bulk of the work was routine, carrying out the same analysis by the same methods every day. Much of the classification of goods could be done on the basis of previous experience or of established "case law" and a good proportion of the work on "damaged goods" involved informed observation and physical sorting of the contaminated from the unharmed, usually by junior assistants. New problems would call for new methods and innovative techniques; most chemists kept well in touch with developments in the science and were respected and well regarded by their professional colleagues in other industries. Nevertheless very little of the daily work could be classed as research; for that it was necessary to wait until after the conclusion of the first world war – things then began to be difficult for the railways.

Now, in this account of laboratory work in the period from 1864 to approximately 1914 there is no mention of engineering and just a bare reference to metallurgy. It may well be asked why, if the railway chemists gave such an excellent service to all departments, there was no similar activity in engineering? The answer is that chemical knowledge was unique to chemists: they worked therefore, among a population of the uninformed on chemistry, somewhat in the position of respected witch doctors or successful conjurers. No matter what was asked of the chemist he almost invariably pulled the rabbit out of the hat. But in the case of engineering the railways were full of engineers, civil, mechanical and signal engineers, a significant number holding positions of considerable responsibility. Years of effectively running successful railway systems which gave a safe and reliable service gave the engineers confidence in their knowledge and ability. When problems arose an engineer saw it as his duty to solve them, or to set his assistants to the task. As for the development of bigger and better locomotives, more comfortable coaching stock, smoother permanent way or better signalling systems, that was very much the responsibility, readily accepted, of "the engineer". Moreover the boundary between development and research is very difficult to define; in classifying all of a particular railways engineer’s innovative work as “development” it is accepted that some injustice may be done. However, in the period under consideration there was little interest in totally new concepts, apart perhaps from eventual electrification. Ideas such as monorails or turbine locomotives were for the science fiction writer, and the distant future. Meanwhile the steam locomotive provided a quite reliable form of traction in a community in which coal was produced in prodigious quantities and where manpower was equally plentiful. Awkward questions about thermal efficiency and the reluctance of men to work on tube cleaning, smokebox cleaning, fire dropping and boiler washout, etc., had not yet begun to be put and would not until after the 1930’s slump. There were of course plenty of problems on a daily basis on locomotives, track and signalling, but these were “normal” in the railway business of the time; in due course “the engineer” would get round to curing each and every one. It would not occur to anyone to attempt to solve problems by the employment of another set of engineers virtually indistinguishable from those already in place. For any very serious or prolonged difficulties it might be considered feasible to refer the matter to an academic at, say, Cambridge or London University, but this happened with extreme rarity.

But – there was, and is, one aspect of engineering on which Chief Engineers felt themselves and their senior assistants to be ill-informed, and where expert opinion was needed. This was the subject of the behaviour of materials, and principally of metals, in service. The suitability of particular metals, especially steel, for service has been judged for many years by the results of a series of standard tests which measure tensile strength, ductility, toughness and hardness. Most specifications quote required values to be obtained in these tests for the various alloys. Unfortunately when a metal component fractured in service it was commonly observed that the stress upon it apparently bore no relation to the breaking stress measured in the standard test and that the fractured component gave no sign of ductility or of toughness. Moreover at this time steelmaking, either by Bessemer converter or in the open hearth furnace, still possessed a strong hint of alchemy, especially when the combined effects of basic slag steelmaking and the heterogeneity of large ingots produced serious defects in the rolled or forged steel product.

Most of the larger railways possessed Test Houses in addition to their Chemical Laboratories. The Test Houses were manned by engineering staff and were equipped to carry out the standard mechanical tests that were applied to the products of the works foundries and forges. They were also employed in making check tests on steel or other metallic products purchased from external suppliers. The staff of the Test Houses were mainly employed in inspection and acceptance of material at the suppliers works before despatch. They were therefore regarded as the experts in this field which straddled the boundary between engineering and metallurgy, although in fact the general level of expertise was not high at that period. But, like many of the chemists there were engineers in the test houses who had enquiring minds, who drew conclusions from observations and who began to develop theories to explain some of the unusual results that were obtained. Seeds were being sown which were to germinate and flourish in the future but only after the upheavals of the 1914-18 war and the subsequent amalgamation of the independent railways into the four great groups.

Chapter 2: The Growth of Research between the Wars

After the Peace Treaty of 1919 there began a slow return to normality in the country, but the Government of the day was reluctant to see the railways which it had controlled as a unit under the wartime Railway Executive return to one hundred and twenty separate companies in various states of economic health. Therefore, as is well known, the big four mainline companies were formed. It is not the intention here to discuss the amalgamation except for its effect on the development and use of scientific method; for this purpose it is necessary to begin with the London Midland and Scottish Railway, the largest of the new groups. Within England the LMS contained three of the major railways of the past: the LNWR, the Midland, and the Lancashire and Yorkshire. In some respects the L&Y had perhaps a slight technical lead thanks to the philosophical and practical legacy of Sir John Aspinall at Horwich. One small example of this was the purchase around the time of the amalgamation of a Haigh fatigue testing machine for the Test House at Horwich. In fact it was never used there but had to wait until George Hughes, the Chief Mechanical Engineer of the L&Y and first CME of the LMS retired and was succeeded by Sir Henry Fowler, who had been CME of the Midland. Fowler decided to amalgamate all the Material Inspection Departments of the constituent companies of the LMS under a man called Treadgold who was to be based at Derby. As a result the unused Haigh testing machine was transferred from Horwich to Derby along with a similarly unused Wöhler fatigue testing machine from Crewe. There were staff transfers also; a young engineer from Horwich, Tom Baldwin, was appointed to take charge of the Derby Test House and he began to study the two machines and their complexities and to put them to work, no easy task with the extremely temperamental Haigh machine.

Meanwhile, the Association of Railway Locomotive Engineers, an organisation of CMEs and their deputies, set up in 1890 to discuss mutual technical problems, became concerned about the high rate of fractures in locomotive laminated bearing springs which were in general use. The rate at which springs had to be changed in running sheds was alarming and there was always the possibility of a complete failure leading to a serious derailment. ARLE decided to approach the National Physical Laboratory, at that time the leading centre in the UK for the study of fatigue of metals, for assistance. The NPL gave them some advice based on a similar problem which they had investigated for road vehicles, and encouraged ARLE to carry out their own tests. Accordingly a suitable machine was designed, built and installed at Ashford Works on the Southern Railway (Maunsell, CME of the Southern, was chairman of ARLE at the time). A long series of tests was carried out and some of the results implemented; the real significance was that another piece of scientific research had been carried out successfully.

Sir Henry Fowler was never renowned as a locomotive engineer; he preferred generally to see Midland designs perpetuated, with other additions made to the fleet by pre-grouping classes of L&Y and LNWR locomotives in small numbers. He was however very interested in science, particularly materials science, and convinced of the potential value of its application to the railway.

Fowler also developed some concern for the rather intractable problem in boilers of water leakage through the screwed ends of the copper stays, which, passing through the water space, secure the inner copper firebox to the outer steel wrapper plate. All locomotive boilers seemed to suffer alike. The projecting stay heads were rivetted over but this did not prevent water trickling or pouring down the copper plate particularly as the boiler began to cool down. Consequently considerable manpower was in use to re-tighten the stays by hammering during running shed repairs.

Probably because the problem was general to users of steam locomotives it was decided to use specialised expertise available within one of the new Research Associations and also to involve the other three railways through the medium of the RCH rather than by approach to the ARLE. Each of the other railways agreed and the British Non-Ferrous Metals Research Association undertook the project, apparently for nothing, on the understanding that each railway company involved would take out a membership subscription. The Research Association seconded a young engineer/metallurgist to the project. His name was T M Herbert; he was given quarters in a little hut in Derby Locomotive Works and made observations on a number of different locomotives in service on the LMS, LNER and the SR. He measured stay head temperatures (by means of fusible inserts) checked dimensions of stays and had analyses made of the firebox gases near to and remote from the plate surface. He achieved a very clear understanding of the processes at work, but apparently did not propose any comprehensive solution to the problem. Certainly in the Stanier and Bulleid regimes the problem was ameliorated by the use of Monel metal and steel stays (for different reasons) and by the practice of fitting nuts on the projecting stay heads.

Whether or not a solution was proposed by Herbert most of the senior railway men involved seem to have been greatly impressed by the thorough and competent way in which the work was done and by the demonstrated value of scientific method in obtaining valuable information on a difficult problem. The result of the work was that T M Herbert was offered in 1928 the post of Scientific Adviser to the LMS, which he accepted, together with the job of secretary to the newly formed Scientific Committee.

By 1930 it was clear that a sufficient head of steam was building up to propel the LMS into providing some kind of formal organisation to carry out scientific research. The President of the railway, Sir Josiah Stamp, who was a forward looking man, could see that technical standards needed to be advanced scientifically and to do that the most effective method was through the formal use of applied science; he therefore took the most important step of inviting an outstanding man of science to become a Vice-President. This was Sir Harold Hartley, who accepted the post in 1930 and became also the first Director of Research. Sir Harold was an established scientist, a physical chemist, of considerable standing. He was a Fellow of Balliol College and a Fellow of the Royal Society, but was also an Industrialist having been a member of the Board of the Gas Light and Coke Company, a Director of Chemical Warfare with the rank of Brigadier General and he later became an enthusiastic promoter of the Institution of Chemical Engineers; he had been knighted in 1928.

Sir Harold’s arrival on the LMS made it clear to all that there would be, and shortly, a much greater use of scientific research. He chaired a committee which drew up plans for the new organisation and submitted them to the Board.

In preparation for these plans, Sir Henry Fowler ceased to be CME of the LMS in 1930, making way for E J Lemon and in 2 years time, W A Stanier and the solution of the locomotive problem. Fowler was appointed Assistant to the Vice President, where amongst other activities he took positive steps to initiate some research work. He took T Baldwin, the young man in charge of the Derby Test House, onto his staff, and recruited S R M Porter, a young Cambridge graduate who had worked briefly on the Swedish Railways, to work with Baldwin. Fowler also took over other staff engaged on quasi-scientific work; these were F Fancutt who as Works Chemist at Wolverton had made a specialism of Paint and was moved with his small team to Derby; W Pritchard who, with the aid of two brothers, ran the textile testing laboratory recently moved up from London; and finally E Millington who rejoiced in the title of Chief Metallurgist and who was based in Derby Carriage and Wagon Works.

A nucleus of a research department therefore existed when the LMS Board was considering the Hartley proposals that were finally approved. The Scientific Research Department of the LMS formally came into existence on 1st January 1933. T M Herbert was placed in executive charge with the title of Research Manager.

The plan for the new department envisaged the creation of six Sections to cover the range of scientific expertise likely to be required. They were:

Chemistry	Paint
Engineering	Textiles
Metallurgy	Library & Information Service

Of the technical sections, only Chemistry, Paint and Textiles could be said to exist at the beginning. The LMS had inherited from its constituent companies five chemical laboratories at Crewe, Derby, Horwich, Glasgow and Stonebridge Park. Once under LMS control these five had been effectively combined as one unit under the control of Dr P Lewis-Dale, previously at Crewe, as the Chief

Chemist LMS. The new Chemical Section was numerically the strongest group even when the new Paint Section was formed by extracting the staff who had previously worked in this specialised field at Wolverton. The concept of a Library and Information Service also pre-dated the formation of the Research Department; Sir Harold Hartley had made the dissemination of relevant scientific information one of T M Herbert's responsibilities in his previous role as Secretary to the Scientific Advisory Committee. Assisted by a Miss H F Parkinson he produced from early 1931 a Monthly Review of Technical Literature for the benefit of technical staff throughout the railway, and offered a facility to loan the referenced articles on request. This service to the LMS, and later to BR, was to continue for many years. By 1935 a translation service was offered. Also in 1935, an additional technical section was added: Physics. Initially its activities were supervised by Mr. M G Bennett who undertook this task in plurality with his responsibilities (to the Chief Civil Engineer) for Lighting and Heating. However, Trevor Eames was the senior full-time member of the Section from an early stage, and later assumed full charge.

The plan for the LMS Research Department included also the provision of a new building specially designed for its purpose. The design was by the LMS Architect W H J Connal; design and construction proceeded quickly. It was situated on London Road, Derby, next to the unlovely building which at that time housed the Locomotive and Carriage and Wagon Drawing Offices. Both buildings lay within the boundaries of the Carriage and Wagon Works. The architectural style can, perhaps unfairly, be described as mid thirties Odeon Cinema, but it raised the visual standard of that part of Derby considerably, although now overshadowed by the attractions of the Railway Technical Centre opposite. The new building was designed to accommodate four Sections, Engineering, Metallurgy, Textiles and Paints, and the Library; and proved very adequate for a number of years. The office and laboratory accommodation was good and initially the library space was generous. Apart from a tall single-storey test hall and workshop, it is a two storied building with long central corridors giving good access to the essential laboratory services that run above the corridor ceilings and are accessed from above. With an eye to future expansion it was designed for the eventual building of a third floor to the same ground plan, the tops of the structural columns projected through the roof for that purpose.

The building was completed in 1935 and the official opening took place on 10th December that year and was a great occasion. The ceremony was performed by Lord Rutherford, who was conveyed to Derby with the other guests in a special train hauled by a 5XP Jubilee class locomotive also bearing the name Lord Rutherford of Nelson. He was accompanied by many senior railway officers and a party of distinguished scientists, including Sir William Bragg and Sir James Jeans; indeed it seemed as though most of the Royal Society was present.

For the first year or so of its existence (while the new laboratories were being built) the Research Department's activities were restricted by lack of space, of equipment and of staff of the right level, but the opportunity was taken in this period to recruit as many senior and experienced men as possible, particularly the heads of the new Sections. It will be seen that the Department fell naturally into two distinct parts; the new which was expected to involve itself in scientific work not previously undertaken on railways (in Britain) and the old, or well established, which would continue with the type of work made familiar over the years. This situation was recognised in the appointment of the Section Heads; those chosen to lead the Chemistry, Paint and Textile Sections, Dr P Lewis-Dale, Mr F Fancutt and Mr W Pritchard, all had years of experience in their fields of railway science. For engineering however the choice fell on Mr F C Johansen, previously employed at the NPL where he had been responsible for work in the wind tunnel for both the LNER and the LMS on the air resistance of passenger trains. Metallurgy was initially in the charge of Mr E Millington who already carried the title of Chief Metallurgist, LMS, but he was soon succeeded by Dr H O'Neill who had already been recruited from Manchester University probably with a view to his eventual promotion to Head of Metallurgy as we shall see in Chapter 8. Dr O'Neill was a physical metallurgist of distinction with a considerable reputation for work in the field of complex ternary and quaternary non-ferrous alloys.

At the same time the opportunity was taken for another change – the setting up of a Works Metallurgists organisation on the LMS. Men in many cases already active in post were officially designated as Works Metallurgists at Crewe, Derby, Horwich and Glasgow St Rollox. Primarily responsible to the appropriate Works Manager they also owed a technical allegiance to the Chief Works Metallurgist, A H C Page, who reported directly to the CME. Thus the new Metallurgical Section in the Research Department was released from all responsibility for day to day metallurgical control in the works except by special invitation.

Viewing the LMS Scientific Research Department in the sober light of New Year 1936 after the excitement of the opening on 10th December 1935 had subsided, it could be safely said that the new body had been well and truly launched on a relatively smooth sea, accompanied by very many good wishes from railwaymen and from renowned scientists. In fact, it was destined to be the main focus for railway research up to and through the war years and to Nationalisation in 1948. Indeed its structure of seven Sections proved very durable and survived Nationalisation by 3 years, the Department continuing under London Midland Region management until the formation of the Railway Executive's Research Department in 1951.

However, while it was the largest, it was not the only centre of scientific endeavour on the railways at the time. The Chemical laboratories of the other three railways continued their work in support of current operations, much as described in Chapter 1, again up to Nationalisation and then under Regional management to 1951. They also took initiatives in new directions where the need arose or where they perceived an opportunity. The GWR's single laboratory at Swindon continued to support, mainly, their Chief Mechanical Engineer. On the LNER, the four Chemical laboratories surviving in 1930 (the Gorton and Inverurie laboratories had been closed) also formed part of the CME's organisation and were located in his four main works at Stratford, Doncaster, Darlington and Glasgow Cowlairs. In that year Mr T Henry Turner took charge, with the title Chief Chemist and Metallurgist, LNER. With his office in Doncaster, he reported directly to the CME, Mr H (later Sir) Nigel Gresley, at King's Cross. An early action under the Turner regime was a comprehensive attack on the problem of locomotive boiler water quality. This involved chemical analysis of all the points of supply, a study of physical and financial data to determine priorities, and then the progressive building of water treatment plants. The chemists subsequently monitored performance. This was pioneering work at the time and produced excellent financial benefits. It was later extended to static boilers and ships and was influential in the drafting of British Standards. T. Henry Turner was also active in smoke abatement and in supporting the other officers of the LNER, including the Civil Engineer. Meanwhile his staff were busy with the usual chemical analyses, with metallurgy, paint – the Forth Bridge was an LNER responsibility – and with the carriage of perishable goods, such as the express fish traffic from Aberdeen.

The Cowlairs laboratory closed in 1936. In 1940, the Stratford laboratory and its junior staff were evacuated to Doncaster. This was fortunate as it turned out, as on 12 January 1941 the laboratory building was destroyed in an air raid. It was never rebuilt. However, the District Chemist Jack Hill continued to work from an office in the works, sending samples to Doncaster for analysis. He was notably successful in formulating a "war" oil, countering supply shortages, and thereby reducing the incidence of bearing failures which had threatened the LNER's ability to carry its wartime traffic.

Later the Eastern Region chemists were much involved, as were their colleagues on other Regions, in the locomotive exchange trials of 1948/49, measuring water quality and the calorific value of coal. Then with the prospect of dieselisation, the Stratford Office took the lead in investigating the atmospheric pollution caused by diesel locomotive exhausts. Trials were carried out in the tunnels on the "widened lines" out of King's Cross, giving results favourable to the diesels.

We shall meet again the Chemical Laboratories of the Eastern and North Eastern Regions (ex LNER), and also of the Western Region (ex GWR) and the Southern Region (ex Southern Railway), in 1951 at the formation of the Railway Executive's Research Department. However first we shall consider an activity that concerned all the "grouped" Railways (to varying extents): the testing of steam locomotives. Then in Chapter 4 we shall discuss the engineering research contribution of the Southern Railway; and then, in some detail in Chapters 5 to 9, the contribution of the LMS Scientific Research Department.

Chapter 3: Locomotive Testing

The testing of steam locomotives has been practised ever since steam traction began, even if the great majority of testing has taken the form of ensuring that a new design of locomotive, or one with major modifications, could haul a train of the required mass over a specified route in accordance with a pre-determined timetable. Normally an observer from the Drawing Office would be present on the footplate and often steps would be taken to determine the mass of coal used on the test run which frequently was made in revenue earning service. This description does not, however, apply in all cases: some railways were concerned to carry out testing in a more scientific manner. This concern expressed itself quite early on in railway history; certainly some countries, such as Russia and the USA, were involved in more precisely defined testing procedures towards the end of the nineteenth century.

In Britain there developed a passionate interest in locomotive testing and the advantages it offered in the 1930s. During this period, although much of the testing was of a routine nature, the methods became much more scientific and certainly akin to many of the practices in laboratories. Moreover, the LMS Research Department became considerably involved even though testing was primarily a CME function.

But to return to the beginning of "scientific" locomotive testing in Britain; it took place first, as one might perhaps expect, on the Great Western Railway in the great period of Churchward as Chief Mechanical Engineer, commencing with the construction in 1901 of a dynamometer car. At this point it is necessary to digress slightly into a consideration of testing procedures.

The simplest method was of course the one already mentioned, in which the trial merely established the locomotive's capability to work a train over a particular route to a given schedule, but this gave little objective evidence on the power developed, and whether this was just adequate for the job, plentiful, or excessive. It was clearly desirable to measure some things in numerical terms, hence the dynamometer car which in the early versions measured drawbar pull and speed and plotted these two quantities on a long roll of graph paper unrolled as the journey progressed and marked by an observer at appropriate moments to indicate mile posts, junctions and stations. Thus the drawbar pull at each point on the journey could be determined from the graph. On these occasions coal was often supplied to the tender bagged in one-hundredweight sacks and the use of each bag duly recorded by communication between footplate and dynamometer car (by electric bell code). Thus there was a rough correlation between coal consumption and the work being done by the engine.

In 1906 the North Eastern Railway built a dynamometer car to the drawings of the GWR. This was followed by the building of generally similar cars by the LNWR, date unknown, and by the L&Y in 1913 so that dynamometer car testing of locomotives was a standard practice on four of the twenty-three main line companies prior to 1913. This form of testing also had disadvantages: firstly that coal and water consumption was of necessity measured over an extended period of time whereas speed and draw bar force were measured instantaneously; but secondly, and principally, it was not generally possible to guarantee long periods of constant power output or boiler evaporation because of continually changing conditions facing the locomotive. Except on parts of the GWR (e.g. the Thames Valley) and on the LNER East Coast Main Line, a feature of British main lines was the constantly changing gradients and curvatures which affected the power required from the locomotive to maintain schedule. A rising gradient called for more steam which required for a few minutes or longer an increased firing rate: when the gradient became falling there was probably still some coal in the firebox which had been added to provide the steam in the climbing phase, and so on. What was needed was an adequate period of constant power output calling for a constant rate of firing. If this could be obtained the real efficiency of the locomotive could be determined and realistic figures for pounds of coal per drawbar horsepower-hour determined together with similar figures for water consumption.

Needless to say the GWR had appreciated this point early on; in 1905 they brought into action at Swindon a static locomotive test plant, on which the locomotive stood with its wheels supported by rollers, the locomotive being restrained from any forward (or reverse) movement. Five rollers were provided to suit a locomotive of 4-6-0 configuration. All the rollers were interconnected by driving belts which in turn drove a shop compressor. In addition the three rollers on which the driving wheels rested were controlled by band brakes hydraulically applied and water cooled. However the total power absorption capacity was limited at this stage to about 500 horsepower.

After the amalgamation of 1923 only the Southern Railway had no dynamometer car and had to make do with engine testing by taking indicator diagrams, a system of recording, by a pencil lead on small sheets of paper, the pressure of steam supplied to a cylinder and its decline as the steam expanded during the piston stroke and exhausted. Subsequently measurements by planimeter of the area under the curve thus drawn gave a value for the work done per stroke from which power developed in the cylinder could be calculated.

However, the newly formed LNER had in H N Gresley a CME who was convinced of the great potential value of a static locomotive test plant to the LNER. He was appointed President of the Institution of Locomotive Engineers in 1927 and used the occasion of his Presidential address to make an impassioned plea for the provision, as a national asset, of such a plant. His remarks were noted particularly by the Department of Scientific and Industrial Research, which in 1928 set up a committee under the Chairmanship of Sir Alfred Ewing to consider the subject. Gresley had already discovered an ally in Sir Henry Fowler of the LMS who became a keen member of the committee. R E L Maunsell and C B Collett were also invited but were less enthusiastic and usually sent “representatives” to meetings. After a few meetings it was decided to appoint a smaller “working party” to progress the matter: this was chaired by Professor W E Dalby of City and Guilds College and with Gresley, Fowler and F S Walley of the DSIR as members; it began work in 1929. The group made positive progress in many ways, deciding on a suitable site for the testing station near to Leeds and familiarising themselves with up to date hydraulic dynamometers, one of which existed at the National Physical Laboratory where it was being prepared to test the power output of road vehicles.

In 1930 the full weight of the economic crisis hit Britain and the committee found it had no option but to wind up its activities and hope for better times ahead.

Gresley, however, was still very anxious to achieve satisfaction and a locomotive testing plant. In 1932 W A Stanier became CME of the LMS and in 1934 Gresley became President of the Institution of Locomotive Engineers for a second time. He repeated his previous plea for a national test plant and obtained a similar result in that the DSIR again decided to take action and a new committee was formed. This time A C G Egerton of the DSIR was in the chair and Gresley, Stanier and Dr H J Gough, Superintendent Engineer of the NPL, were members. This committee assembled the facts, which made a strong case for the testing plant, and in 1935 a formal proposal was made to the LMS Board of Directors that there should be such a plant, jointly owned by the LMS and LNER, and that it should be at Derby so as to obtain advantages from the proximity of the LMS Research Department and the Locomotive Works. During the discussions it had also been proposed that the test plant, once built, should not be controlled by the CME but by the Research Department, drawing an analogy with the LMS Accounts Department which performed the accounting function within every department of the railway in order to provide also a continuing “audit” of each department. As might be expected this proposal was an anathema to the CME Department that had always regarded locomotive testing as one of its cherished responsibilities. It was finally agreed to accept a suggestion by Sir Harold Hartley which envisaged a controlling body which included himself and Sir Ralph Wedgwood of the LNER together with Stanier and Gresley.

In October 1935 the LMS Board agreed in principle to the provision of a static locomotive test station, under the control of the Locomotive Testing Committee named above. Detailed planning was now devolved on Gresley, Stanier, Herbert and Dr H J Gough. Almost immediately they paid a visit to the newly opened testing station of the SNCF at Vitry near Paris. The French put on an impressive show for them. An Etat Railways 4-6-2 was driven into the Test Hall, mounted on the rollers, coupled to the drawbar and run on test at full speed for over an hour. When the test stopped the locomotive was driven off the roller system and recoupled to its tender ready to depart.

The committee returned fired with enthusiasm: they settled to the work necessary to bring the project to fruition. They decided, again, on a site, this time Rugby, in an angle where the LNER’s

Great Central Main Line crossed the LMS West Coast Main Line. Outline specifications were drawn up. The testing plant was to be equipped with 7 rollers of which 5 were to be coupled to hydraulic brakes or dynamometers, each of which was to be capable of absorbing 1200 HP; the maximum testing speed was to be 130 mph. Total power absorption was to be limited to 4500 HP in the first instance, but extendable to 6000 HP. The costs of the plant were estimated to be a total of £165,000 which included the provision of a new dynamometer car to replace the old L&Y car.

In 1936, while planning for the Rugby plant was in full spate a new factor was injected by the Research Department, and by Dr Ivan Andrews of the Engineering Section in particular. Andrews had joined railway research from the British Thomson Houston Company at Rugby, but he had already obtained some railway experience in the USA. He was greatly interested in locomotive testing and impressed by the pioneering work of Lomonossoff of the Russian Railways and its latest development by Professor Nordmann in Germany. Following their lead, Andrews took up the other aspect of testing, i.e. on-track testing under constant power output or constant speed conditions. Lomonossoff had concerned himself with this method of testing, in addition to the use of the static test plant which he had caused to be built at Kiev. Constant-conditions “on track” testing was said to have the advantage that aerodynamic effects were not ignored and that train resistance could also be measured; it was therefore a form of testing which led to the gathering of more accurate data on which timetabling could be based. The Russians were, of course, fortunate in that in their vast country they had several routes on which the track was dead straight for many miles and also other routes with a very great length of constant gradient. Driving a train on these routes at constant speed required a constant level of power output, ideal for locomotive testing. The Polish Railways also had very long straight and level routes which were used for locomotive testing. In addition both the German Reichsbahn and the French Railways had similar views on the desirability of on-track testing although both systems had static locomotive testing plants. These two railways had developed the idea of providing a variable load in the train hauled by the locomotive under test: this was achieved by the use of counter pressure steam locomotives in which steam could be used in the cylinders to oppose motion. Two different methods known as the Riggenbach or the Le Chatelier counter pressure system had been used. There was also an example in England: the LNER used an old North Eastern Railway B13 4-6-0 equipped with counter pressure equipment in testing from 1934 to 1949.

There were of course disadvantages in the simple counter pressure locomotive system: speed of response to changing conditions encountered by the test locomotive was one. Dr Andrews decided to tackle the problem more scientifically, using an electrical analogue to the counter pressure system. He produced a scheme for the construction of three bogie coaches, each equipped with axle hung traction motors which were in fact connected as generators whose electrical output could be dissipated in resistors, i.e. a rheostatic braking system. Control of the generated power, and therefore of the load provided by a coach was done by variation of the field of each generator and was achieved by a comparison of actual train speed with a pre-set desired speed. If the two differed a voltage was generated, which when amplified could be used to vary the generator field strength through the action of thyratrons, until the actual and desired speeds were coincident again. This system produced a very rapid response to changes in train speed.

Andrews worked up this scheme in conjunction with BTH at Rugby and put forward, through Dr Johansen and Herbert in the Research Department to Sir Harold Hartley, a proposal to construct three power absorbing coaches. Each would have the same power absorption capacity but different gear ratios would be used in each so as to cover different testing conditions at different speeds using one, two or all three of the Mobile Test Units (or MTUs as they came to be called) as required.

Hartley was convinced of the value of the scheme and put it forward to the Locomotive Testing Committee, where initially it was treated with reservations on the grounds that the proposal would divert funds, resources and possibly work from the Rugby plant, as well as having the disadvantage of being a Research Department and not a CME initiative. However, it was eventually agreed that the three MTUs would form a useful adjunct to static locomotive testing and that the predicted volume of locomotive testing was such that the Rugby plant would be overwhelmed for the first few years of its life. A formal proposal was made to the LMS Board’s Mechanical and Electrical Engineering Committee for the construction of three MTUs by them in July 1936.

Meanwhile another branch of the Research Department had become involved in locomotive testing, this time the chemists. The account of the scheming and activities which led to the authorisation of both test plant and MTUs may have given the impression that no locomotive testing was taking place pending the completion of all these marvellous new facilities. This was far from the case, the Testing Section of the Locomotive Drawing Office at Derby being kept busy with the two dynamometer cars on a variety of projects, such as the new Stanier locomotives and some of the older "problem children" such as the LNWR Claughtons. There was therefore a considerable interest not only in testing but also in achieving more accurate and reliable results. Two self-weighing tenders had been built to avoid the tribulations of bagging and unbagging and recording the weight of locomotive coal used on tests. Now questions were being asked as to evaporative efficiency of boilers, leading inexorably to questions as to the efficiency of combustion. How much combustible material, as soot, coal char and unburned gas was passing out of the chimney? Dr Lewis-Dale, head of the Chemical Section, addressed himself to this problem. He decided to tackle it by measurement of the thermal conductivity of samples of smoke box gas which was drawn off into tubes by an ejector and then divided into samples for the determination of oxygen, hydrogen, carbon monoxide and carbon dioxide, solid particles being extracted from the gaseous sample and dealt with, by combustion, separately. The process involved pipelines from the smoke box along the outside of the locomotive and the tender to the laboratory car in which the apparatus was mounted. Flexible connections were provided between vehicles: the whole system was complicated and involved much ingenuity to achieve reliability and freedom from leakage at the many joints. Once inside the laboratory car the samples containing the individual gases were separately tested for gas content by measurement of thermal conductivity. The apparatus had been developed and calibrated by Bairstow and Binns, both at the time members of the Crewe laboratory. The system, although complicated in underlying theory, permitted continuous measurements while the locomotive was running, the figures for the amount of the various gases present being recorded on a chart. Account was also taken of the heat contained in flue gases and the sensible heat in the exhaust steam, all of which enabled a heat balance to be drawn up, which showed that of the total heat generated by the combustion of the coal 70% was effectively used in steam generation under normal conditions, a figure which fell to 50% when the locomotive was working hard. As a result of this work, it was decided to install smoke box gas analysis equipment on the test plant at Rugby, but the general use of the procedure in routine dynamometer car testing did not proceed for long, probably due to the large demand for additional manpower and time which the method created; normally at least ten people were involved in smoke box gas analysis on each test run.

While the Locomotive Testing Sub-Committee continued work on the general planning of the Rugby plant, and Dr Andrews was supervising design and construction of the MTUs, the joint controlling committee of the locomotive testing project was following up earlier proposals that the test plant should be a truly national asset, and to this end discussions were being held with the private locomotive building industry on the possible use by them of the plant to test locomotives built for export. The proposal that the industry, represented by the Locomotive and Allied Manufacturers Association, should inject some money into the project in return for access to the test plant was not greatly welcomed and many difficulties were raised. The principal problem was one of gauge since LAMA pointed out that the majority of export locomotives were designed for gauges other than the standard 4 ft 8½ inches. The Testing Committee accepted this problem and produced estimates for additional rollers or multiple-gauge rollers which would accommodate say three of the most common non-standard gauges. A secondary problem, that of transporting non-standard gauge locomotives to and from Rugby had to be accepted as an inherent and expensive difficulty. Finally LAMA was asked to say definitely would it join the scheme or not. The reply was negative and accompanied by reasons of peculiar logic. The industry, which claimed to be collectively the largest supplier of locomotives in the world, could not afford the expenditure involved (probably about £50,000) but in addition it was argued that if, for example, a sample locomotive from each major order was tested at Rugby before despatch it would be necessary also for the manufacturing companies to become involved in research, as was the case with their European competitors who used the testing facilities available to them in their own countries. Locomotive design in the UK, it was claimed, depended primarily for its success on long experience and on intuitive knowledge of what was required!

A major step forward was taken by the Sub Committee when in 1937 R C Bond was appointed as Superintending Engineer of the project at Rugby. There followed a period of intense work in which designs and detailed drawings for the structure of the plant and the buildings began to appear. Orders were placed on Amsler's of Switzerland for the drawbar dynamometer and some integrator equipment; Heenan and Froude were contracted to design and construct the whole of the roller and brake equipment for the absorption of power.

Sadly the clouds of war were gathering; in 1939 it became necessary to close down the work on the Rugby test plant and the MTUs. Only the frame of the building at Rugby was erected, but the first of the MTUs was completed and was used briefly before being stored for the duration.

After the war the work at Rugby was resumed as soon as a building licence could be obtained. By then R C Bond had moved on to higher things and his place as Superintending Engineer was taken by D W Sanford of the Derby Locomotive Drawing Office. Eventually the work was completed under D R Carling and it became possible to plan a testing programme.

The Rugby plant was formally opened in October 1948 but by then the two principal protagonists of its construction were no longer active. Gresley who had been knighted in 1936 had died suddenly in 1941; Stanier had also been knighted at the end of the war but had left his position as CME for important national duties during the war. It was therefore very fitting that at the official opening of the test plant by the Minister of Transport the Rt Hon Alfred Barnes, there was a locomotive on test: it was ex LNER A4 Pacific "Sir Nigel Gresley". The locomotive which hauled the special train carrying the Minister and guests to Rugby was ex LMS Duchess class 4-6-2 46256 "Sir William A Stanier, F R S".

Locomotive testing at Rugby was in full swing by the end of 1949 and those seriously interested in the programme of work should consult D R Carling's papers to the Institution of Locomotive Engineers and to the Newcomen Society. A considerable number of locomotives passed over the rollers at Rugby or hauled one or more of the MTUs on test runs in the ensuing years. Examples of all of the BR standard locomotive classes were tested, some on an uprated test plant at Swindon. In general the results obtained could be described as valuable rather than spectacular, although the latter adjective could well be applied to the testing of a Merchant Navy class locomotive, where the tests revealed the very great effectiveness of the Bulleid boiler as a steam raiser, and simultaneously showed up the weaknesses of the chain driven valve gear which at high speeds caused the inside cylinder to actively oppose the work done by the other two.

During this period the power absorption capacity of the Swindon plant was raised although insufficiently to cope with the most powerful locomotives of the day. Mr S O Ell (Sam Ell) had been placed in charge of locomotive testing, occupying an office which proclaimed him as head of Development and Research. Perhaps because of limited power capacity at Swindon Ell took to on-track testing at constant speed or constant evaporative rate, and by research into the theory and the development and use of steam chest and blast pipe pressure measurements raised the scientific standards of locomotive testing again. Meanwhile, Dr Andrews was also pursuing increased accuracy in testing with the MTUs. He was anxious to eliminate errors due to variation in the weight of coal in the firebox at the beginning and at the end of a test period: to this end he designed a firegrate which was supported by load cells using strain gauges to measure and record the mass of firegrate plus coal. Unfortunately it was too early in the development of strain gauge techniques for success in this venture.

It took 20 years from 1927 to achieve a modern locomotive test plant. The next fifteen years were filled with locomotive testing activity, with the emphasis of on-track testing shifting towards measurement of train resistance. But by 1964 the demand for steam locomotive testing had almost disappeared. Valuable work on the efficiency of the Giesl ejector blastpipe was nullified by the fact that it was too late in the day for steam. The same applied to a Research Department proposal for very high superheat temperatures. Proposals were made for other forms of traction, diesel, electric and gas turbine, to be tested and some work was done, but the plant needed a sixth roller brake dynamometer to cope with Co-Co locomotives and to obtain one to the design and characteristic of the first five was not practicable. Some work was done by the Electrical Research Department on measurement of adhesion on the test plant, but interest was fading rapidly because of the ease with which locomotives with electrical transmission could be monitored on track. At the end of 1964 Electrical Research took over the premises: by 1966 the plant was the property of BR Research but without further potentiality and it was finally closed. The MTUs were gradually stood down and one still survives in the National Railway Museum's collection. Testing at Swindon continued principally as on-track testing into the period of the diesel hydraulic locomotives whose transmission characteristics did not lend themselves to voltmeter and ammeter recording; but with the disappearance of the hydraulics that activity also came to an end.

After a long and difficult gestation period the locomotive testing plant and to some extent the MTUs came into existence too late: the good influence on steam locomotive development and practice was exerted in the dying days of that form of traction.

Chapter 4: The Southern Railway Contribution

The second topic we shall consider before returning to the story of research on the LMS, is the contribution to engineering science made by the Southern Railway.

It is intriguing to note that what occurred on the Southern resulted largely from the influence and work of three individuals: a management decision to support a research department never materialised although for a brief period there was a faint possibility that it might.

These three individuals were diverse in character, but each was primarily interested in materials. The first in chronological order was Frank Hargreaves, a chemist/metallurgist whose career commenced on the South Eastern & Chatham Railway in the Chemical Laboratory at Ashford, where in the 1920s he did excellent and original research into the physical and metallurgical properties of the white metal alloys used to form anti-friction bearing surfaces in axleboxes and connecting rod big ends, etc., for locomotives, carriages and wagons. These alloys were extremely important in the running of railways prior to the introduction of roller bearings; there were, however, many "hot boxes". Hargreaves' work, although published, got little official recognition but because he added to the knowledge of the load carrying capacity of white metals it is probable that the thickness and shape of the bearing metal inserts used on the Southern were influenced by his work.

In 1937 a new semi-automated iron foundry came into production at Eastleigh and Hargreaves was sent there as metallurgist-in-charge. Additionally he extended his work to the provision of general laboratory facilities covering metal analysis and testing, control of welding, etc., and generally filled successfully the role of "tame scientist" or "trouble shooter" for the whole of the ex-London & South Western area of the Southern Railway (still far from being an integrated unit). The construction of Merchant Navy locomotives at Eastleigh gave him an opportunity to extend further his activities, particularly with the radiographic examination of welds. Later he developed a very successful specialised technique for the repair welding of severe cracks that were frequently to be found in the inner steel firebox plates of these engines. He continued his service to Eastleigh during the epic problems of the building of the Leader class locomotives.

Hargreaves had considerable scientific talents and the ability to use them to solve practical engineering problems. He could have advanced in the CME organisation to much wider responsibilities but for his personality. Unfortunately he was opinionated, rather quarrelsome and unable to suffer gladly fools or even those of a different opinion; these characteristics helped to keep him at Eastleigh.

Meanwhile at Ashford, a contemporary of Hargreaves was coming to the fore, Basil R Byrne. Unlike Hargreaves, who was a University graduate, Byrne had been apprenticed to the London Brighton & South Coast Railway at Brighton, but his technical education was limited by the lack of college facilities in the seaside town. Shortly before the 1923 amalgamation his apprenticeship was completed and he was then employed in the Test House on the routine testing of materials. Because his formal education was so limited, he strove to acquire the necessary technical knowledge by private study. As a result he became fascinated by and totally in love with science and particularly physics; his reading tended therefore to concentrate on optics, radiation, atomic structure, crystallography and metallurgy, to some extent at the expense of engineering subjects such as heat engines and kinematics.

In the 1923 amalgamation, the SECR became the dominant partner in the Southern group; Maunsell, now CME Southern Railway, decreed that Ashford should become the headquarters for the CME Department, and as a result the Test House at Brighton was closed down. Byrne and the testing machines were transferred to what was subsequently called the Physical Laboratory, Ashford, and joined the materials inspection section under a man named Taylor. The new boss was a bureaucrat who ran the largely clerical system of directing the outside inspectors to those factories where material for the Southern was ready for delivery and then checking their reports. He would not allow Byrne access to the "mysteries" of the system, confining him strictly to the testing of samples sent in by the inspectors. Apart from the fact that Byrne and his boss Taylor did not frequently communicate by the spoken word, this system suited Byrne since his work load was light; he thus had plenty of time in which to pursue his reading and to conduct his own experiments. Physics led him into more advanced optics and then to the subject of photoelasticity, newly described by M Frocht and by Coker and Filon. It now becomes necessary to attempt a brief description of this rather complex phenomenon. Photoelasticity derives from the fact that certain transparent "plastic" materials such as celluloid, perspex and some epoxy resins show the phenomenon of "birefringence" when viewed in polarised light while subject at the same time to stress. If, therefore, a two dimensional model of an engineering component made in, say, perspex is loaded as it would be in service (to scale) and examined in a beam of polarised light, a pattern of coloured interference fringes will be seen, particularly in the more highly stressed areas of the model. The colours and the number of fringes are proportional to the level of stress and also indicate the direction of stress. Thus a survey of the whole model can be used as a study of the stress distribution in magnitude and direction.

Byrne built his own polariscope, principally from second-hand lenses and odds and ends bought at his own expense. He was soon able to perform photoelastic tests, but without attracting any interest from his superiors until the CME, O V S Bulleid, learned of his work. It was apparent that the availability of this stress procedure was very timely as Bulleid, then engaged on the design of the Merchant Navy class locomotives, decided to move away from the classic spoked driving wheel in favour of a double plate type wheel similar to those used in the USA. He had a design ready, the BFB wheel (joint with Firth Brown) but before finally committing himself he wished to be satisfied that the BFB wheel was superior in terms of the level of stress. Here the problem and the new technique came together: Byrne was invited or instructed to make the comparison on his new-fangled and home made polariscope. Byrne, with the assistance of the Works toolroom, produced beautiful 1/10 scale models in celluloid of the two wheels and, in a scientific "tour de force", a detailed comparison of the stresses was completed, reaching the safe conclusion that the BFB wheel was greatly superior.

This brought Byrne very much to the attention of Bulleid so that other projects and enquiries came his way. Meanwhile Taylor retired; Byrne became "Materials Supervisor" which meant that in addition to his scientific work he had to administer the inspection organisation. However, the new post gave him more power and also access to Southern Railway money for the purchase of equipment. This enabled him to pursue another great personal interest, X-radiography and its industrial applications. In furtherance of this enthusiasm he was fortunate to learn of a general practitioner in the West Country who was about to retire and wished to sell his diagnostic X-ray set of 150 kV capacity. Byrne was able to purchase it for £40; installation in the Ashford Physical Laboratory was very much more expensive because of its complex and elderly power and control system. It was very slow in use on engineering materials as well as being dangerous since it was neither ray nor shockproof. But it would penetrate 3/4" of steel plate and could be used on realistically sized welded joints, simulating those being designed for the Merchant Navy boilers. The acquisition of this X-ray unit was superbly timed. It made an immediate impression on the quality of welding at Ashford, demonstrated without question the value of the procedure and caused a new Philips 150 kV set to be purchased for use at Eastleigh on the Merchant Navy boilers constructed there, Hargreaves being one of the principal beneficiaries. It is interesting to recall that at about the same period a Philips X-ray unit of the same type was acquired by the Metallurgical Section of the LMS Research Department. Meanwhile Byrne contrived to have a greatly superior 250 kV X-ray unit imported from the USA for use in his laboratory and subsequently at Brighton when construction of West Country class locomotives started there in 1944.

Byrne was fortunate in that his personal scientific interests led to his ability to make major contributions to the Southern; his timing was also first class. These qualities paid personal dividends as in 1944 he was appointed Bulleid's Research Assistant and allowed to recruit staff (previously he had had one technical assistant and about ten inspectors scattered across the industrial North) and to acquire the basic necessities in laboratory equipment. The Physical Laboratory then became not only the home of the inspection service but also provided a metallurgical service to Ashford, Brighton and Lancing Works and advice on, and control of, welding in the same works and in some of the larger sheds and depots. (Hargreaves provided a similar service at Eastleigh and to the old LSWR steam sheds). But the principal activity in the Ashford Laboratory was research into a variety of problems, mostly of a metallurgical nature, and the development of apparatus and techniques for the measurement of stress. The photoelastic bench was upgraded with proper optical equipment, much work was done on the use of hand-held mechanical extensometers and of course there was the new wonder tool, the electric resistance strain gauge, for which the measuring apparatus had to be made and the techniques of application mastered. In the middle of all this activity the new science of ultrasonic testing (then known as supersonic testing) burst upon the scene as a potential solution to the problem of detecting cracks in carriage axles. It became instantly essential to understand the principles behind this process, to work out the procedures for application to Southern carriage axles, to train staff to operate equipment, and to install the method in Lancing and Eastleigh Works and the electric stock depots around London. Meanwhile, metallurgical research was being concentrated on the cause of the relatively frequent fracture of tyres on the driving wheels of electric multiple unit suburban trains, and on the cause and possible cure of corrosion fatigue cracking of inner firebox plates and stays in Merchant Navy boilers. This problem was in fact cured simply and elegantly by Bulleid’s decision to apply the TIA water treatment to these locomotives.

In the first years of peace after 1945, applied science seemed to stand high in public opinion; most industries were setting up research groups and because of this atmosphere and of his successes Byrne’s star was in the ascendant within the CME Department. He was transferred to Brighton to be available to Bulleid and the Design Office, leaving his staff, now ten in number, qualified or semi-qualified, to carry out the laboratory work at Ashford. Outside the railway, in learned society circles he was regarded as an authority on industrial radiography and, a little later, on non-destructive testing in general.

Unfortunately, there was a snag, a worm-i-the-bud, in that the laboratory had no formal or established existence as seen by Southern Railway management, nor did it receive any official instructions on policy or on projects to investigate. Much of the work was based on the inclinations and interests of the staff, so that the situation could arise in which one member of the staff was engaged in high vacuum technology in order to make measurements of internal stress by X-ray diffraction methods, while another was, at the request of Ashford Works, setting up a system for the training and testing of welders and a third was busy trying to find out why, reputedly, the tail lamp on the up Golden Arrow train was, much too frequently, going out on the stretch between Ashford and Tonbridge.

The bubble burst in 1949 when O V S Bulleid retired. His successor was S B Warder, an electrical engineer, whose appointment foreshadowed the future traction policy of the Southern Region. Warder soon showed that those who had been close to Bulleid were no longer in favour; Byrne was sent back to Ashford and the special connection between the Physical Laboratory and CME headquarters was broken. Fortunately, requests for work were now coming from other departments or from officers of the new Railway Executive; the laboratory had to concentrate on a variety of carriage and wagon studies, on sub-contracted fatigue testing of rails and on a major examination of the propagation of ultrasound in objects like axles in order to understand the peculiar results being obtained wherever ultrasonic testing was practised.

On the 1st January 1951 the British Railways Research Department came into being and the Ashford Laboratory became part of its Engineering Division, Byrne being given the title of Assistant Superintendent. An exciting and valuable era subsided into more orthodox activities, probably of greater value to the railway industry.

The other contemporary of Hargreaves and Byrne was A H Toms, a conventionally trained graduate civil engineer. Initially he became known following the speedy and efficient way in which he organised the repair and re-opening to traffic of the viaduct in Brighton, which carries the Newhaven and Hastings line, after it had been severely damaged by a German bomb. However, Toms’ main interest was in research and particularly in soil mechanics, the science of the load carrying capacity and modes of failure of the whole range of subsoils from chalk through rocks, sands and gravels to the various forms of clay. Toms was made the Chief Civil Engineer's Research Assistant about 1945 and took on the responsibility for soil mechanics research and for the

Wimbledon laboratory which dealt mainly with problems of rails and civil engineering materials. In that position he conducted a noteworthy investigation into the problems of Folkestone Warren, a narrow stretch of land lying between the sea and the chalk cliffs on which runs the main line from Folkestone to Dover. The towering cliffs, about 500 ft high, are based on a layer of gault, a form of clay, which is relatively weak. Periodically the gault has failed by shear and slips away, leaving the chalk cliff undermined locally which may cause a major chalk fall which in turn cuts the railway line. Major slips, all of which interrupted rail traffic for long periods, occurred in 1897, in 1915 (a great embarrassment at the time) and in 1937. The investigation showed the relationship between periods of heavy rain and the probability of slip, measured the shear strength of the gault in various states and calculated the most likely surfaces and directions on which slip in the gault would occur. Since the vertical face of the cliffs lay in a curve it was also possible to determine a focal point for all the slip directions. This focus lay just offshore and Toms proposed to lock the system by the construction of a massive block of concrete on the focal point. This was done about 1948-50 and appears to have been wholly successful in that there were no further interruptions of rail traffic in the Warren during the next forty years.

Toms was also concerned with soil failures, usually in clay formations, under the running lines. On a weak clay subsoil the dynamic forces produced by trains, particularly at rail joints, cause shear failure in the clay which “puddles” in wet weather and pumps up between the sleepers leaving voids underneath. Toms (like some others) was developing a remedial system called “blanketing” in which the clay beneath the track is removed to a depth of, say, one metre and is replaced by sand or other granular material upon which the track is relaid. To design such works effectively requires not only a knowledge of the strength of the infill materials but also of the stress levels to be expected in the soil at various depths as known wheel loads are applied. To determine these stresses Toms had designed new and elegant pressure cells to measure sub-surface stress; this gave rise to some valuable co-operation between the Civil and Mechanical research groups, as the Ashford Laboratory was called in to provide the strain gauging expertise and the electronic recording apparatus – not always with the reliability that Toms would have wished.

Later on Toms developed an interest in the problem of rail head corrugation which, he was able to show, was related both to the metallurgical treatment of the rail head, the so-called Sorbitic process, and to a critical level of traffic density. When the new BR Research Department was formed, it was decided that Toms and his little team should stay with the Regional Civil Engineer and that research and development work on soil mechanics should remain a regional activity, which it did for a number of years. The Southern was later joined in this type of work by the Western Region and it was not until 1965 that the Derby Laboratories finally took over responsibility for soil mechanics research.

It may seem, in retrospect, that the Southern Railway nearly had a Scientific Research Department of its own. Unfortunately top management – the General Manager and the Board of Directors – never appeared to have the vision of the potential value of research that, for example, Lord Stamp and Sir Harold Hartley exhibited on the LMS. The initiative and the enthusiasm for the application of science to railway problems came from three individuals and principally from two; both served the railway well. Having said that, it must be recorded that there was a period in 1947 when the three Chief Engineers, acting almost in concert for once, were seized with the idea of having an engineering laboratory in common. An empty building was chosen; it was the old Brighton Works Coppersmiths shop, vacant for many years except for a large flock of feral pigeons. It was situated at the top of a steep embankment, immediately adjacent to the Hastings and Newhaven line. Its interior was to be divided into three equal parts, one for each department. There were to be no common services; the Chief Electrical Engineer reserved the right to send staff and equipment from London Bridge to the laboratory only when a problem arose or tests were to be carried out; co-operative research on mutual problems was not envisaged. Perhaps it was as well that the coming of nationalisation and the British Transport Commission’s Research Committee put a swift end to these rather bizarre plans!

Chapter 5: Control of the LMS Research Work

We return now to take up the story of the LMS Scientific Research Department, introduced in Chapter 2.

Once it was established in 1933, control of the day to day work of the organisation was of course vested in T M Herbert who reported to Sir Harold Hartley, receiving guidance from him on policy and on the type of work to be done. By itself this system would have required Hartley and Herbert to be omniscient so far as the needs and problems of the LMS were concerned: alternatively they might have rapidly run out of ideas (or steam?). Fortunately Sir Harold had foreseen a need to obtain expert advice and guidance before actually launching the Research Department and had arranged the formation of an Advisory Committee, which he chaired and which included among its members not only the principal Technical Officers of the railway but also, by invitation, a number of distinguished scientists from the world outside the LMS.

The Advisory Committee on Scientific Research came into being in 1930, before the Research Department was formed. Its first meeting was attended by Sir Josiah Stamp, the President, who gave a formal blessing to the new body and promised its members that they would have the full backing of the LMS Board in their deliberations and decisions. Afterwards Hartley described his policy which at that stage was not to increase significantly the laboratory research carried out on the LMS beyond that currently undertaken by the small group of people who had been assembled around Sir Henry Fowler in Derby and Herbert in London. Instead it was proposed to concentrate on utilisation, to the greatest possible extent, of the work of the various DSIR Research Associations which were then springing up, and to rely also on assistance, both advisory and practical, from appropriate University Departments such as the Cambridge Engineering Laboratory. However, an additional plan was that each Department of the LMS should nominate one or two of its brighter young assistants to be responsible for development within their Departments, for which purpose they were to be detached from routine duties and set to think in offices away from the hurly-burly of the day. It seems that no further reference to this scheme exists!

The composition of the Advisory Committee at its first meeting on 2 July 1930 was as follows:

Sir Harold Hartley FRS	Chairman
Sir Herbert Jackson FRS	Director of Research, British Scientific Instrument Research Association
Sir Harold Carpenter FRS	Professor of Metallurgy, Royal School of Mines
Mr William Rintoul	Joint Research Manager, Imperial Chemical Industries Limited
Dr F E Smith FRS	Secretary of the Royal Society and Secretary to the Department of Scientific and Industrial Research
Sir Henry Fowler	Chief Mechanical Engineer, LMS[1]
E J H Lemon	Carriage and Wagon Superintendent, LMS

[1] Sir Henry Fowler was soon appointed Special Assistant to the Vice President (Sir Harold Hartley) with E J H Lemon succeeding him as Chief Mechanical Engineer, both appointments effective from I January 1931.

A Newlands	Chief Civil Engineer, LMS
A F Bound	Chief Signal and Telegraph Engineer, LMS
J Sayers	Telegraph Superintendent, LMS (retired)
T M Herbert	Research Manager, LMS, and Secretary

Apologies for absence were received from Mr A C G Egerton, a fifth external member, and from Mr F A Cortez Leigh, the LMS Electrical Engineer. Egerton, already an FRS, was later Professor of Chemical Technology at Imperial College and also a member of the DSIR Committee examining the need for a Locomotive Testing Station.

Having listened to the introductory speeches, the Committee commenced its first discussion on the needs of the Railway in terms of scientific research as seen by those present. The result was an interesting division between the scientists and the railway officers as can be judged by the initial list of problems quoted below:

1) The wheel/rail interface. This was to include adhesion, wear and the motion of wheels as they proceeded along the track. It was rapidly agreed that it was difficult to make any start on adhesion in the scientific sense.
2) Durability and the cleaning of painted surfaces. On this subject much had already been done; it was therefore decided to set up a working party consisting of Sir Herbert Jackson, Rintoul, Newlands and Lemon to consider the most profitable lines to follow in future.
3) Primary and secondary cells, a subject on which Dr F E Smith would advise.
4) The need for harder tyre steels.
5) The intensity of light transmitted through red Fresnel lenses. Sir Herbert Jackson undertook to help on this as well.

The mixture of subjects proposed was broad, extending from fairly profound science to rather banal practicality; but this was of course the first time the group had collectively addressed the problems. A similar mixture has always tended to exist in railway research programmes.

The Committee began to get into its stride at subsequent meetings. At the second Mr Sayers raised the problem of interference suffered by light current circuits, such as those used in signalling, from neighbouring power cables. This subject was dubbed "parallelism", a somewhat unlikely name, but the subject was to be raised at most of the future meetings and of course still exists, especially as electronic control of locomotives injects more powerful high frequency signals into power lines.

At the fifth meeting the appointment to the Committee was announced of one more distinguished scientist, C E Inglis, professor of engineering at Cambridge.

During its second year of existence the Committee was promoting the development of welding, particularly of alloy steels such as the 2% nickel steel which was beginning to be used for boiler plate. Reports were also being received on the work being done by the LMS research staff, an example of which was the activities of Millington on the heat treatment of rails. Sandberg "sorbitic" rails were highly thought of, particularly on the Southern Railway, and Millington was trying to produce the same favourable micro-structure by quenching from finish rolling temperature in a blast of icy air instead of the steam used in the Sandbert patent!

Extramural work in other laboratories was initiated on Committee advice and the regular reports on these investigations were always discussed. Two good examples follow. The first was the work undertaken by Professor Inglis at the Engineering Laboratory, Cambridge, arising from the initial discussion of the wear of rails and tyres and was concerned with the motion of railway wheelsets as they proceeded along the track. At Cambridge a model railway track was constructed and arrangements made to project a model bogie along it and record the resulting motion. Usually this consisted of a growing to side-to-side oscillation of the wheelsets (indicative of dynamic instability), whose rate of growth, frequency and wavelength varied with the angle of coning of the wheel treads and the forward speed. A considerable number of variable factors were studied, including the freedom given to the wheelset to move laterally and to yaw. It was shown that a reduction in the clearances between axlebox and guide brought about an immediate improvement by increasing the wavelength of the lateral motion and reducing the severity of the instability. The investigator, Captain R D Davies, came to an Advisory Committee meeting in October 1933 to describe his work, and also took the opportunity to propose experiments at full scale with various bogie modifications, including reduced clearances. This was rather coolly received by Lemon, who had just completed a series of experiments covering much the same ground. Davies was first asked to re-analyse these earlier results. This introduced a considerable delay. However, eventually new experiments were commissioned, mainly concerned with reduced wheel coning, but their rather desultory progress was halted by the war. In fact, Davies had not identified the key to stable running, and nearly 30 years were destined to pass before this problem was finally solved.

The second example of extramural work was undertaken at the National Physical Laboratory; the costs were shared between LMS and LNER, and at a later stage by the Southern. The work concerned investigation of the resistance to train motion arising from its passage through the air. The work was done in the NPL wind tunnel by F C Johansen, prior to his recruitment onto the staff of the LMS. He had detailed models constructed (at 1/40th scale) of a Royal Scot locomotive and several LMS and LNER coaches, and also used two larger models of LNER engines nos. 4472 and 10000. The effect of simple head winds and of side winds at various angles were studied at simulated train speeds up to 80 mph. It was shown that of air resistance to the train 40% was due to the locomotive and roughly 60% to the coaches. Worthwhile reductions in resistance could be achieved by a domed smoke box front and a fairing from cab roof to tender. In the case of coaching stock the biggest source of air resistance was the bogie, running gear and sub floor equipment.

Many of the results of this NPL work were in effect incorporated into the streamlined locomotives and trains on LMS and LNER which appeared at the time of the coronation in 1936, but were not more widely applied to other locomotives or coach sets probably because of the pleading of the maintenance men.[2] Nevertheless it seemed clear that up to 30% of air resistance, which formed the major source of train resistance at 80 mph or more, could be saved by the simple modifications proposed.

At the end of the Committee’s second year of existence a large number of items of research had been identified and some were in progress, but the volume of work to be done, particularly in the investigation of fatigue failures of tyres, carriage axles and laminated springs was such that W Rintoul strongly advised Sir Harold Hartley to change his initial policy and to set up a fully staffed and equipped LMS Research Department so that the necessary work could be done “in house”: this Hartley proceeded to do. As a result, the Research Department was instituted, staff were recruited and it began to grow in capacity. The load on the Advisory Committee also grew since there were more items to discuss including reports from Derby on some projects and progress on others to be considered. It became clearly too much for the whole Committee to deal with all the projects in the detail required, and it was therefore decided to arrange for seven specialised groups to be formed to deal with Engineering (2), Chemistry, Metallurgy, Paint Technology, Textiles and “Amenities of Travel” respectively. Each group, composed mainly of Committee members, held meetings in between those of the main Committee (which met 3 or 4 times a year), attending the latter also in order to report their activities. As the new Section Heads were appointed they were expected to attend at the appropriate group meetings.

Some of the external members of the Committee were now becoming very closely and personally associated with railway problems and the increasing capacity of the Research Department to solve them. This applied particularly to Sir Herbert Jackson, a man whose wide range of scientific contacts made him especially valuable. He presented the infant Engineering Division with one of the first permanently sealed high vacuum cathode ray tubes. Previously such tubes had been unwieldy in use (and rare) because each had to be continuously pumped to the high vacuum required. Sadly Sir Herbert died in December 1936. So well valued was his contribution that the LMS Board decided to

[2] The streamline form of the LMS Coronation locomotive was developed in the Derby wind tunnel, see page 31.

institute a prize in his name as a commemoration: it was to be awarded annually for the best technical paper submitted by a member of the Research staff. It was first awarded in 1938.

Membership of the Committee was now slowly changing as some of the original members retired or, in the cases of Sir Herbert Jackson and Mr William Rintoul, died. New names like Sir Thomas Merton, Sir Joseph Barcroft and Dr Desch begin to appear in the records.

The list of subjects proposed or considered was also continually growing, with the same mixture of important scientific studies and minor practical problems (which were, nevertheless, frequently of "major" importance in terms of their economic significance to the LMS). Still keeping firmly to the need to understand wheel/rail interaction the Committee caused T Baldwin to be detached for a six months intensive study of the technical literature on the wear of metals and then to design a wear testing machine. Later a Dr Schnurmann of the Cambridge Cavendish Laboratory was given a special 3 year contract to study and report on the current state of scientific knowledge on dry friction. But at the later meeting at which the first results from the wear testing machine were presented (and had a critical reception) the Committee also considered the following:

- Pre-cooling versus dry ice protection for strawberries in transit.
- Specifications for brushes.
- Determination of the amount of unburned carbon in Class 7P boilers.
- Fatigue tests on welded joints in boiler-plate steel.
- The new British Standard Specification for bullseye lenses for head and tail lamps.
- Classification of rail failures.

It should be noted that these and other potential items for research were all connected with current problems. There was virtually no looking to the future and the possible shape of the railway and its technical equipment in, say, 25 years time. This was almost certainly due to the constitution of the Committee whereon many of the technical matters discussed were raised by the railway officers present. Of these the Civil Engineer presided over a remarkable degree of standardisation in track components and construction; shortages of softwood for sleepers or of manpower for maintenance had not yet raised their ugly heads. The Signal Engineers, on the other hand, were extremely conservative; for them progress and new ideas came very slowly and usually from the equipment manufacturers. But the mechanical engineers under Stanier were in a ferment of change as every effort was made to overcome the legacy of large numbers of Midland Locomotives that were too small for the traffic and of London & North Western locomotives that had been so unreliable for so long. During the period from 1933 to the outbreak of war the turbine locomotive No. 6202 was brought into service, the streamlined Coronation class 4-6-2's designed while the great problem of the inability of the Class 5X Jubilees to steam properly gave rise to major re-design of superheater, tube arrangement and blast pipe dimensions. But neither the Research Department nor the Advisory Committee seems to have been in any way involved except for the NPL wind tunnel work already described. Similarly there was no Research involvement (again apart from aerodynamics) during the CME's flirtation with a diesel engined railcar in the late 1930s. However, this failure to involve Research cannot be regarded as a calculated snub; the hierarchy of the CME Department had always regarded itself as totally responsible for design and development of rolling stock and traction power. It was, however, prepared to admit the need for applied science when it came to materials problems and service failures, and to appreciate the value of exotic equipment like wind tunnels and (slowly) of advanced mathematics and computation.

Nevertheless the work of the Advisory Committee was undoubtedly of great value to the growing Research Department because of the quality of the scientific advice and of the guidance given which prevented the young department from becoming inbred and failing to look over the boundary wall around the LMS railway. But perhaps its greatest value came from the Committee's elevated status and the high standing of its membership which encouraged the research workers and discouraged those who might otherwise have opposed or tried to impede the Department's work. But not all the research work came as a result of the Committee's deliberations; much came directly as appeals for assistance from Works Managers and other Engineering Officers and much was initiated internally either to improve the Department's capabilities or its technical and instrumental equipment. In fact the full nature of the work needs the following four chapters for its description.

Before proceeding to that stage, however, it is necessary to refer to another Committee set up in January 1939 to control the finances of the Research Department. This was the Scientific Research Committee of the LMS Board. It was composed of "junior" board members and apparently regarded as something of a training ground for the "juniors" before promotion to the important Board Committees such as Traffic, Finance or Staff and Establishment.

The Scientific Research Committee in 1939 consisted of four Knights, one Earl and one Lord or Viscount, with Sir Harold Hartley and the long suffering T M Herbert in attendance. The Chairman for the first seven meetings was Sir Alan Anderson, thereafter Sir Robert Greig. The Committee was not concerned with the research programme (although it formally "accepted" the minutes of the Advisory Committee on Scientific Research) but with the authorisation of expenditure on capital equipment, on extramural research activities and membership of external Research Associations, on additional accommodation and most importantly on staff salaries, or at least on their periodic augmentation. This was also the body which approved annually the award of the Herbert Jackson Prize, the first relating to 1938 (approved in January 1939). In some years both the prize and a "Herbert Jackson Medal" were awarded. The names of all the prizewinners and their papers are preserved in the Committee minutes. In the later years it was minuted that increasing difficulty was experienced in obtaining sufficient applications for the prize, and in 1946 both prize and medal were awarded to J O Cowburn for his paper on a leakage detecting instrument for use on vacuum braked vehicles. Also in 1946, the scope of the prize was extended to accept papers from any technical department and in fact the last award of all in 1947 was made to a "passed fireman" who wrote an excellent report on the burning of fuel oil in locomotive fireboxes.

One major item of interest in this Committee's Minutes remains. This was a report by T M Herbert in 1946 on a project for extending the capacity of the London Road laboratories by building on another floor. This possibility had been foreseen by the Architect who had arranged for the tops of the columns to project through the flat roof for this purpose, as we have seen. Unfortunately this vertical extension was proposed during the immediate post-war period when all building was strictly controlled by licence which was unobtainable for this project, thus forcing the Committee to discuss other solutions such as a "semi-temporary" addition to the building at ground level. In fact the matter of additional accommodation was never resolved by the Scientific Research Committee, which ceased to operate at the end of 1947 when nationalisation was imminent. It must be recorded however that the Committee's attitudes to the Research Department was clearly beneficent and encouraging. If the salary increases agreed were somewhat meagre they were in fact of course the recommendations of the Labour and Establishment Department.

Chapter 6: The LMS Research Department at Work – Mechanical Engineering

Once officially formed in 1933 the LMS Research Department commenced operations fairly slowly, faced with the problems of obtaining equipment, accommodation and staff – although that comment is strictly only applicable to the two new Sections, Engineering and Metallurgy. The Chemical Section inherited the laboratories of those railways absorbed into the LMS, namely Crewe, Derby, Horwich, Glasgow and Stonebridge Park, the temporary laboratories formed in London and at Wolverton having been closed. An earlier change had been the extraction of all the work connected with paint (and the staff involved) in setting up the Paint Section in Derby Carriage and Wagon Works in 1930.

Even the new Sections did not start absolutely from zero since the staff of each, although few in number and scattered among houses in London or in Works accommodation in Derby, had been in action for various periods of time before 1933, some of them administered by Herbert and the others at Derby loosely controlled for a few years by Sir Henry Fowler. For these staff, the change in 1933 represented a formalisation and an intensification of their activities as new staff were recruited and plans made for future work and for the acquisition of the necessary apparatus.

In the Engineering Section at the outset, the key figure was T Baldwin, ensconced in an office in the Derby Test House and with the right of access to the various testing machines and the workshop. Three major fatigue failure problems were passed to him through the CME Department and the Advisory Committee: they were the cases of fracture of locomotive tyres, of the increasing number of carriage axles found cracked or which broke in service (infrequently but dangerously) and the ever present problem of locomotive laminated spring failure. The first difficulty with these projects, except for springs, was the lack of suitable testing machines. There was the Haigh machine, purchased in a fit of enthusiasm by the Lancashire and Yorkshire Railway in 1922, difficult to control and not seriously used; there was also the Ashford spring testing machine, but for the axle problem there was nothing suitable. Baldwin's first task therefore was design: design of equipment to make the Haigh both usable and controllable, and design, ab initio, of a large "Wöhler" type rotating bending machine on which reasonably sized model axles carrying press fitted wheels could be tested. For help in this work he obtained the services of a young draughtsman, R G Jarvis (who was later to become Design Engineer, Southern Region, where he was responsible for the re-building of the Merchant Navy locomotives). Baldwin himself dealt with the Haigh machine but was then diverted into the theoretical study of "wear" as required by the Advisory Committee. This led to more design work; this time of a wear testing machine and of the "rail and tyre machine".

He had also been joined by a colleague, S R M Porter, who, after graduating at Cambridge, had spent a brief period on the Swedish Railways: he was an engineer with strong mathematical leanings. He arrived to undertake work on the riding of locomotives, complementary to that of Dr R D Davies of Cambridge University Engineering Laboratory and principally concerned with the negotiation of curves. Porter commenced by making visual and photographic observation of the transverse movement of the locomotive wheels relative to the rails, for which purpose he had a low platform constructed between the frames of a 2 cylinder (outside cylinder) locomotive. He rode on this platform beneath the boiler and between the driving axles a number of times but the extent of the possible observations and their accuracy was extremely limited. Turning to more theoretical methods he made a careful study of the work of a German, Übelacker, who had been commissioned by the International Railway Congress to examine what was known of the locomotive riding problem and to write a critical review of the subject for the IRC Journal. Armed with his own observations and analyses and with Übelaker's work Porter wrote a very valuable book, "The Mechanics of a Locomotive on a Curved Track". Unfortunately he was taken ill shortly afterwards and died of pneumonia in 1934, the Department losing a very promising young engineer and scientist.

Towards the end of 1935 the new building (known today as Hartley House) was occupied and officially opened, as already described. Dr F C Johansen, who had been for a time with the small Research outpost at Euston, arrived to take charge of the Engineering Section as Senior Research Engineer. Previously, as we have seen, he had worked at the National Physical Laboratory where he came to the favourable notice of Herbert and Hartley by virtue of his work in the wind tunnel on the air resistance offered to trains at speed and the potentialities of streamlining. Herbert had also become convinced of the value of wind tunnel facilities within the Research Department and had obtained authority for a suitable installation. Initially it was to be at Stonebridge Park but it was reported to the Advisory Committee early in 1934 that a suitable site for the wind tunnel had been found in the Derby Locomotive Works paint shop. After the necessary preliminaries (which included begging a second-hand propeller from the Fairey Aviation Company and a second-hand electric motor from Horwich Works) the wind tunnel was completed in early 1936. It was a fairly small tunnel of 4ft 6in by 3ft 6in working section and 60mph maximum air velocity, but it was immediately put to useful work. The first tests determined the best streamlined head and tail shapes for an advanced articulated 3-car diesel multiple unit being designed by the LMS at the time. The second series, more famously, determined the streamlined form for Stanier's Coronation class locomotives. In both cases, Johansen's recommendations were accepted and implemented. In these early experiments, Johansen was assisted by J Jones. Soon he engaged a new member of staff, Dennis Peacock, to assist with the aerodynamic work, and this was to prove Peacock's principal concern for the whole of his career.

Dr Johansen quickly proved himself to be a great asset to the infant Engineering Section. He was energetic and enthusiastic and able to inspire and sustain enthusiasm among his staff. Equally important he was a very able engineering scientist of wide ranging capabilities; moreover, having come from a prestigious organisation outside the railway, he was less inclined to defer automatically to autocratic senior Engineering Officers than were the home grown researchers.

However, the early work of the Section in its new quarters owed most to Baldwin's preparatory activities. Those machines, the design of which he had initiated and guided, were now completed and ready to be used, including the Haigh machine which had been tamed of its previous bad and unstable performance by an early example of negative feedback control. An error signal was derived from the test specimen deflection (if it varied beyond the preset limits) and this signal was amplified by a triode valve to a voltage of sufficient value to be able to adjust appropriately the speed of the magnetic drive.

The first problem to be studied on the Haigh machine was that of locomotive tyres. The complementary statistical exercise showed that there had been 54 cases of tyres breaking in service or found cracked upon inspection in the last 4 years, each a potential disaster. Testing began on specimens cut from tyres but usually retaining the original surface of the bore which had been in contact with the rim of the wheel. Normally the bore was rather coarsely machined because it was believed by some that the roughness of the surface helped to maintain a good grip on the wheel. However the fatigue tests showed this to be unwise: the fatigue strength of the coarse specimens was some 70% less than that of comparable specimens machined with the then new carbide tipped tools at high speeds. It was also observed that the type of tyre fastening, such as the setscrew or rivet fastening, had a deleterious effect on the strength of the tyre so that the investigation concluded with strong recommendations to improve the machining practice and to change to the Gibson ring fastening. These were accepted quickly by the CME (W A Stanier) who had new tyre boring machines installed at Crewe and Derby while making his own equally valuable contribution, the change to the triangular section wheel rim. The whole investigation ended in complete success; tyre failures on steam locomotives rapidly dwindled to almost vanishing point.

The work on the cause of cracking in carriage axles was also underway. The fatigue testing machine known as the "press-fit Wöhler" designed by Baldwin and Jarvis to make rotating bending tests on 2" diameter scale model wheel and axle assemblies, was brought into use by E Warlow-Davies who had joined the Department after doing a period of research at Oxford University under Professor Southwell. At first, attention was concentrated on the problem of "fretting corrosion" which occurred at the interface between wheel and axle in the model axles and also at full scale; but later it was discovered that a relatively simple change of dimensions and geometry where the wheel fitted on the axle would produce a significant improvement to the strength of the assembly. This was accepted by the CME but could not be implemented on a large scale at that time, partly because of the cost (there were probably about 25,000 vehicles affected) but also because it was now war time, which meant that workshop resources were no longer available for that type of work.

The wear testing machine had also been completed and was put to work. The test pieces were two discs of the steel(s) to be tested, which were mounted and driven so that their cylindrical surfaces rubbed against each other with considerable pressure as they rotated. It was found difficult to run the tests properly at first; the test pieces became hot, wore unevenly, generated a lot of noise and quantities of metallic wear particles. Moreover, the results were at times erratic and inconsistent. It became necessary to spend a great deal of time working out improved testing techniques, but eventually this was done and routine testing was able to commence in the manner originally expected. But before any considerable body of results was accumulated which would enable different tyre and rail steels to be placed in order of wear resistance, the work load in the laboratory had grown to such an extent that the time-consuming wear tests had to be put on one side and in fact remained untouched for a number of years.

The Engineering Section now numbered eleven qualified staff (1936) of whom about half came from outside the railway. The other half had all been railway engineering apprentices who had obtained degrees or other engineering qualifications by part-time study during their apprenticeships. They were supported by a well equipped workshop with a staff of four craftsmen supervised by a chargehand, Bill George, who scared many a young research assistant into proper respect for good engineering workshop practice: he was universally respected for his total commitment to the laboratory and its progress.

The list of material failure problems originally identified by the Advisory Committee and the CME still contained one item not yet completed; this was the case of the very high failure rate of locomotive laminated springs. This was a continuing saga from the days of the long elegantly curved springs of the horse drawn carriage from which the springs for locomotives, carriages and wagons were clearly derived. Unfortunately the manufacturing procedures had not greatly advanced over the years, a fact which hampered scientific attempts to improve the service life, particularly of locomotive springs. In the 1920s the Association of Railway Locomotive Engineers had made praiseworthy attempts to improve the laminated spring by instigating the construction of a fatigue testing machine capable of testing single plates or pairs of plates. The machine was built at Ashford Works and used there for a long series of tests which clearly demonstrated the major role of surface decarburisation of the plates in causing the low fatigue strength observed in practice. Doubt was also cast on the suitability of the plain carbon spring steel in the water hardened state. Sadly the investigation ground to a halt with the conclusion that nothing could be done without incurring great cost. Twenty years later the study was resumed at Derby on the same Ashford testing machine. This time (and it was now war time) the Ministry of Supply, concerned at this large and wasteful use of steel, proposed the examination of the shot peening process claimed in the USA to be capable of producing great improvements in fatigue strength. In addition the superior silico-manganese steels were to be tested, as was the possibility of using interleaving with non-metallic materials to eliminate the damage due to adjacent plates rubbing and fretting when the spring flexed in service. A long programme of tests was carried out; the results were only partially satisfactory. Shot peening improved the strength of the plates as expected, but there were complications; interleaving did not work at all with the materials tested; silico-manganese steels were an improvement but were erratic in performance and Stanier was not prepared to sanction the increased cost. E S Cox, despite having published figures which showed that on many classes of locomotive springs would not survive for a full year, called a halt to the work at least until a large machine capable of testing full size springs was available, and that effectively brought the spring programme to a stop for another twenty years. When it was resumed the problem was exactly the same as on the two previous occasions.

The research into locomotive tyres and carriage axles both had satisfactory outcomes; the work on wear and on springs was disappointing, but a 50% success rate was perhaps reasonable. There were of course subjects for study other than materials problems; it is now appropriate to consider some of these, and probably the most important question and the most difficult at the period under discussion was that of measurement. Almost all physical research work involves the activity of measurement of physical quantities in order to find out what is happening in the subject being examined and to provide a basis for any explanatory theories. This is particularly true of engineering research in which measurement of such quantities as temperature, pressure, velocity, acceleration, force and strain, etc., are inevitably required. In addition it is not enough to measure static values of these quantities since in many engineering cases the quantities often vary rapidly. That was, and is, very much the case with railway engineering and posed severe problems for the young Research Department because of a marked lack of established methods of detecting the instantaneous value of a quantity, of displaying that value and of recording it in a permanent form. Velocity, temperature and pressure could be turned into electrical quantities and displayed and read provided that they did not change too rapidly, but not so in the case of strain, acceleration or displacement.

It was imperative for the Engineering Section in particular to break out from the limitations of the traditional railway reliance on stop watch and six inch ruler as the tools of measurement: the first step came in the use of the cine-camera. Such a camera, provided that it was of reasonable quality and capable of running at least up to 64 frames/second, gave not only the ability to slow down movement but also by frame to frame analysis the possibility of measuring displacement and velocity of the items being filmed, and to deduce from those figures such other quantities as acceleration and force. In consequence it became an important tool for a few years; Johansen pushed the capacity of the cine-camera further by the purchase of a high-speed camera capable of filming at 3000 frames/sec although it was rarely used at its maximum speed.

The next step was to make use of photo-elasticity. This has already been mentioned in Chapter 4 where Byrne's use of the method on the Southern was described. Photo-elasticity could provide a reliable picture of stress distribution by using a model of the component to be examined; with some difficulty numerical values could also be put to the stresses observed. Accordingly a photo-elastic bench specified by Cyril Newberry was designed and constructed at Derby. Having both the resources of money and the workshop behind the project it was considerably superior in most respects to Byrne's apparatus built largely of odds and ends. The Derby photo-elastic unit was soon in use on the determination of the stress distribution in bull head and flat bottomed rails with Newberry in charge of that work as well as of cine-photography.

But the ability to measure stress in a component directly was still a major objective. This became possible about 1938 through the purchase of some Swiss light-weight mechanical extensometers which could be fastened to a component so as to measure the extension or compression experienced as the component was loaded. Changes in length of about 0.00005" in a base length of 1" could be measured, equivalent to a stress in steel of about 0.6 tons/sq in. However, these and similar hand held instruments produced in the Ashford lab were slow and cumbersome in use as well as inaccurate if the temperature changed in the course of the test. Greater hope was raised when a number of "scratch extensometers" arrived from America following a visit to the USA by Herbert in which he met that famous scientist-inventor, de Forest. The scratch extensometer consisted of two separate pieces designed to be fastened to the test specimen 2" apart. One piece carried an arm which had a hard metal point on the end and reached to the other part which carried a flat piece of highly polished steel (the target) on which the point of the first arm rested. When the test piece experienced strain the two parts of the gauge moved towards or away from each other leaving a scratch on the target of length equal to the strain experienced. A neat feature in the assembly ensured that the pointer did not track back on the same line but moved progressively over the target so as to leave a time history in scratches of the various strains which had occurred to the test piece. Again the gauge was difficult to affix satisfactorily in practice (e.g. to a rail) and a measuring microscope was required to read the length of the scratches; nevertheless it was a considerable step forward since for example the gauge could be applied to a rail in track and removed after the passage of one or more trains. It would then carry on the target a series of scratches corresponding in length to the stress induced in the rail by the passage of each axle.

For some time a few scratch extensometers constituted the principal item in the Engineering Division's stress measurement armoury, but eventually, after a second visit by Herbert to the States a considerable prize was acquired in the form of a number of the very new electric resistance strain gauges (hereafter known simply as strain gauges). They were seized upon with avidity by Baldwin who set the staff on to make some at Derby. In essence the strain gauge was a grid of fine wire mounted on a thin paper or plastic base and having two soldering tags; initially it was about 1" long with an electrical resistance of about 100 ohms. In use the paper base of the gauge was securely cemented to the article on which it was desired to measure stress and the gauge connected electrically usually in a bridge circuit. Now if the article carrying the gauge experienced strain, that change in length was transmitted to the wires of the gauge extending or compressing them minutely but sufficiently to change the resistance by an amount that could be measured and which was proportional to the strain in the object carrying the gauge.

Derby was soon in the business of making (slowly) examples of the new strain gauge and finding out how to use them. Rolls Royce at Derby were introduced to the new technique by a gift of a few LMS made gauges. However, for two or three years attention had to be concentrated on establishing all the laboratory techniques essential for the correct use of the gauges. These included choice of cement, drying and protecting the cemented gauges, devising suitable electrical circuitry and methods of calibration. Eventually all this was done and apparatus built for switching between different gauges so that a number could be in use simultaneously. Fortunately the gauges were relatively cheap, but also irrecoverable after use.

It is difficult to overemphasise the importance of the strain gauge to research in general and railway research in particular. From 1945 onwards it was possible to forget all the complicated struggles to measure, not very precisely, the stress at one point on a structure; the strain gauge made it possible, with little more effort, to measure stress at 50 points at the same time. But it must be recalled that these were for a long time only “static” measurements made while an external load was applied and removed from the structure or component under test, strain gauge readings being taken under both conditions. The real prize would be the ability to measure stress under “dynamic” or real service conditions when stresses would most likely be varying rapidly with time as for example in a locomotive bogie at speed. In this case, although the basic strain gauge procedures still applied, the problem was to capture the signal from the gauge and display it, or preferably record it, which required the use of electronic techniques which at that time did not exist although they could be specified theoretically. It was clear that it would be necessary to energise the strain gauge bridge with a high frequency alternating voltage, and to amplify the small strain signals using an amplifier similar in performance to a high-grade audio amplifier. The amplified signal would be put on a cathode ray oscilloscope but in order to record the trace a special camera, in which the film ran continuously through the film gate, was designed and manufactured by the laboratory. This specialised type of recording camera was not readily available on the commercial market. The necessary work started in Derby during the war. Two “channels” were in operation fairly quickly but the problem involved in recording a greater number of strain gauges were severe, since a complete set of amplifiers etc. had to be provided for each strain gauge channel. A twin channel cathode ray oscilloscope became available in 1947. Meanwhile the use of strain gauges was spreading into the field of indirect measurement. For example pressures (or vacuums) could be measured by strain gauges cemented to a diaphragm plate or more simply to a pipe, and weights could be recorded by supporting the article to be weighed (a tank part-filled with liquid?) on four strain gauged “weighbars”. But the basic anomaly still existed in that it was possible for example to put forty strain gauges on a bridge and record the strain from each while a test locomotive stood on the bridge, but only possible to record from two of them while the locomotive ran across the bridge. All this resulted in a very considerable load of work. In consequence much work in design and manufacture of electronic equipment, advising on the use of strain gauges, calibrating batches of gauges, etc., devolved on a small group of staff who later became known as the Instrumentation Section under John Littlewood. This marked the beginning of a structure in the Engineering Section which had up to then existed organisationally with a Chief, Dr Johansen, a deputy Chief, Tom Baldwin, and about a dozen or so Indians of roughly equal status. The growth of both work and staff brought about the move towards some specialisation and so a number of groups appeared such as Instrumentation, Drawing Office, Wind Tunnel, Fatigue Testing and Permanent Way. Not all the staff were allocated to a specialisation at this stage.

The art and science of measurement having advanced and provided a number of tools for the researchers, what use was made of them? The study of vehicle riding which required close observation of wheel position relative to the rail has already been mentioned and Newberry took this up again using a cine camera mounted in the guard's van of the Liverpool-Southport electric stock to observe the lateral motion of wheels with different tyre profiles. In effect some of Davies' work on model wheels at Cambridge was repeated at full scale using various profiles or angles of coning on the treads. An attempt was then made to produce mathematical equations based on these observations which could predict the sinusoidal motion and its wavelength and frequency. Some of the results reported were sufficiently promising for Stanier to have all the coach wheels on one of the Coronation Scot trainsets turned to zero coning, or cylindrical treads: the riding was certainly not impaired although difficulties were experienced in turning both tyres to precisely the same diameter on an axle, an equality which was essential because the self centering action of a coned wheel pair had been lost. However, the experiment on the Coronation Scot faded away with the outbreak of war. No connection between wheel behaviour and coach riding was established by these experiments and the attempt to find a mathematical solution foundered on complexity and the large number of equations involved, in a pre-computer age.

Another and more spectacular use of cine-photography occurred following Herbert's visit to the Altoona locomotive testing plant of the Pennsylvania Railroad in the USA. One of the American engineers, in describing the working of the test plant, emphasised the problem of damage to the plant and in particular to the dynamometers on which the wheels of the test locomotive were supported. The damage was caused by the out-of-balance forces normally produced by 2 cylinder locomotives at speed. These vertical forces were due to the practice of balancing within the driving wheels not only the rotating out of balance of the engine, but also a large proportion of the reciprocating masses. Failure to provide some reciprocating mass balance usually resulted in a violent horizontal swaying couple applied to the locomotive. Practice around the world varied but in both Britain and America it was normal to balance 65% of the reciprocating mass on 2 cylinder engines. The discussion at Altoona was reported to the Advisory Committee who in considering it were no doubt influenced by restrictions put on certain types of locomotive by the Civil Engineer because of the hammerblow. Johansen received instructions from Herbert to investigate; as this was in the pre-strain gauge era he had no means of measuring any out-of-balance forces, especially at the high speeds at which they were generated: he therefore opted for the use of cine-photography.

Three Class 5 locomotives were chosen: No. 5043 was in standard condition with 65% of reciprocating masses balanced; the other two were modified, No. 5464 to 50% reciprocating balance and No. 5406 to 30% balance. The test was arranged on a Sunday on a quiet stretch of track at Castle Donington, where three rail lengths were carefully levelled, marked and painted so that rail deflection could be observed; the rails were then thoroughly oiled on the running surface. With the cine camera set to run at 64 frames/sec the first locomotive No. 5043 was driven on to the test length with regulator wide open. The engine slipped violently and progressed over the test length at about 15 miles per hour, the driving wheels rotating at an equivalent speed of just over 100 miles per hour. The driving wheels could be seen to lift off the rail by 2.4 inches; half a wheel revolution later the rail was deflected downwards by 0.75 inches. This was faithfully recorded by camera, the figures being derived from frame by frame analysis of the film. The other locomotives were tested similarly; No. 5464 had just visible separation of wheels from rail at 108 miles per hour but the wheels of No. 5406 remained firmly in contact with the rail at a similar speed; however the trailing coupled wheels were observed to suffer violent lateral oscillation.

The experiment was an undoubted success; it led to the general reduction to 50% reciprocating balance for modern 2 cylinder locomotives which was to be continued into BR days. It is doubtful if it was also a success politically since it demonstrated that the railway mechanical engineers had got it wrong for a long time; it was also taken by the CME Department as another case of the Research Department getting involved in areas which were strictly a CME responsibility. The CME hierarchy were already upset by Dr Ivan Andrews' foray into their territory with his successful plan to change the nature of locomotive testing by the construction of the Mobile Test Units. Fortunately, perhaps, Andrews was then being kept quiet by all the work required to produce the MTUs.

A good example of the use of strain gauges, albeit in a static role, is provided by the case of locomotive frame fractures. In 1939-40 it became obvious that a serious situation was developing in locomotive availability due to the number in which extensive cracking had developed in the frames usually just behind the driving axle horn guides. This was not a new phenomenon but the situation was getting worse as the cracks which were repaired by welding cracked more quickly than before. This was due to two causes: firstly the welding was often of poor quality and secondly it was clear that the welded joint had a much lower fatigue strength than did the virgin plate. These two aspects were tackled by strenuous efforts by G Foster, the welding engineer, to improve weld quality and to remove welds from the highly stressed areas by cutting out large sections of frame plate and replacing it with new plate welded in to the original with simple welds in areas of relatively low stress. In both of these he was assisted by the use of the Research Department's new Philips X-ray set. But it soon became obvious that with the passage of time the fractures were re-occurring. The CME had little option but to ask the Engineering Section to investigate the problem. Fortunately, at the time the request was received, about 1946, considerable familiarity with the use of strain gauges had been obtained. Dr Johansen caused a full size section of a Class 5 frame to be built in the laboratory complete with all details including horn guides, horn stays, etc.; strain gauges were affixed in the areas around the crack sites and elsewhere in order to get a picture of the stress distribution. Piston loads were applied by screw jacks. Inevitably high stress was found at the corners of the horn space and the investigation continued into causes and potential cures. In essence it was clear that the design of the horn guides, the offset loading of the frames through the axleboxes to the hornguides and the poor design of the hornstays were the principal contributors to the high stresses. Various alternatives such as hornblock castings and improved hornstays and securing methods were examined and the best selected for use: these improvements were perpetuated in the designs for the BR standard locomotives which began to appear three to four years later. This was a very successful and important investigation, the first using strain gauges in any number; it was completed with a mathematical stress analysis carried out by Dr Andrews making use of Professor Southwell's new "relaxation" method.

This chapter has described some of the activities of the Engineering Section but has been largely confined to work for the Mechanical Engineering function. It is not, however, a comprehensive list of projects undertaken between 1933 and 1947. Equally valuable work done for the Chief Civil Engineer is described in the next Chapter. It must also be emphasised that a considerable number of projects have not been mentioned especially those, mostly small items, carried out for individual engineers in the vast engineering empire of the CME Department of the LMS, which included Motive Power Depots, Main Works like Crewe and Derby and Outdoor Machinery Engineers' equipment. Often only advice or a few simple tests were required but in aggregate this formed a load sufficient to delay official projects from time to time and added to the pressure for more staff.

Chapter 7: The LMS Research Department at Work – Civil Engineering

There is a marked distinction between the Civil and the Mechanical Engineering functions in any railway: this was particularly so with the LMS. In the first place the difference arises because the Mechanical Engineer is concerned with moving equipment, such as locomotives, carriages and wagons obviously, but also with road vehicles and a vast amount of outdoor machinery such as lifts, pumps, cranes, etc. The Civil Engineer, on the other hand, is almost solely responsible for fixed, unmoving, structures: the track, bridges, the earthworks which accommodate both; and for buildings such as stations, motive power depots, etc.

The second major difference revolves around standardisation. The CME Department of the LMS had about 10,000 steam locomotives originating from 10 different companies; among these were about 600 ex Midland Class 4 0-6-0 engines but this was the highest level of locomotive standardisation in 1933. Carriages and wagons showed a greater degree of standardisation but it was far from complete. On the other hand the Civil Engineer's standards of track construction extended over the greater part of the system and were virtually identical with the standards existing on the other major railways. The Mechanical Engineer was bound to have a variety of problems with his heterogeneous fleet, the Civil Engineer unlikely to have many problems because track standards had evolved slowly over many years. Rails were almost universally 95 lb/yd bull-head, sitting in cast iron chairs secured to creosote-impregnated soft-wood sleepers laid at 24 per 60ft rail length; the 60ft rails were joined by standard 4-hole fishplates, the whole track being laid on limestone or granite ballast.

However, maintenance work was fairly heavy; each section of track was walked daily by a lengthman who looked for defects such as cracks in rails, missing keys, loose fishplates, etc. Because of the marked reduction in vertical stiffness at rail joints, they slowly became pounded down so that sleepers at rail joints had to be lifted regularly and ballast packed underneath to restore the level of the running surface or "top". Fishplates had to be removed once or twice a year and oiled in order that their intended function of permitting expansion and contraction was not impaired.

Due to these differences, research developed differently in the Civil and Mechanical engineering functions. At the early meetings of the Advisory Committee the only items discussed of interest to the Civils were the rather vague and long term proposals on rail wear and the possibility of classifying different types of rail failure. At that time cracked and broken rails were replaced automatically without the benefit of an inquest except in the most unusual cases: since there were no statistics few conclusions could be drawn on even the most common type of failure. The Advisory Committee's suggestions were therefore most apposite; the study and recording of failures commenced, in the Metallurgy Section.

But through attendance at Advisory Committee meetings the Civil Engineer became aware that he could obtain some assistance from the Research Department with experimental work for which he did not have facilities – although his initial approach seems to have been to use the Research manpower only on experiments or tests which he or his assistants had designed. At this time ideas were also surfacing in the Research and Experiment Committee, a combined LMS/LNER body which was an offshoot of the joint committee on locomotive testing and which was beginning to discuss the distant prospect of long welded rails.

Whatever the birthplace there were two ideas which appeared quite quickly and demanded some action. The first was the need to find an alternative to the standard 95 lb/yd bull-head rail which was regularly showing distress at the joints. The second was to eliminate rail joints as far as possible; this required some positive moves towards solving the problems of welded rails.

To replace the bull-head rail would necessitate the use of a flat-bottomed rail section similar to that already widely used in the USA and on many European Railways. Some FB rails of 113 lb/yd had already been used on a small scale but the design was somewhat empirical and needed to be tested scientifically. It was known that an FB rail would be stronger vertically and would deflect less under wheel loads; but it was also necessary to know how its stiffness and stress would change as wear of the rail head took place and also what was the joint stiffness when fishplates were fitted and tightened. The Chief Civil Engineer therefore instructed the Research Department to make calculations and stress and stiffness measurements on both the BH and the new FB rail sections for different degrees of head wear. The work fell to J C Loach, a mechanical engineer by training, who had been a Horwich apprentice and a contemporary of Baldwin. Charles Loach had a liking for precision in all his work and measurements; he was also rather pedantic and appeared didactic in speech. He had already been involved to some degree in the technology of rails when he was the designer of the rail and tyre machine. He measured stresses in rail ends in the laboratory using the Swiss Huggenburger extensometers, the results showing clearly the superiority of the FB rail over the BH both in terms of stress and deflection for all degrees of head wear.

The advent of the scratch extensometer made it possible for the rail end stress measurements to be repeated on running lines with trains as the natural source of loads in the rails. Loach was particularly ingenious in fixing these instruments to different parts of the rail section in order to obtain as much data as possible. His results, particularly those from severely dipped joints, not only confirmed the greater strength of the FB rails but also demonstrated the high level of rail stress which occurred in these conditions. He had developed some expertise in permanent way matters and although there was still a tendency for the Civil Engineer to design the tests which he wished the researchers to perform, Loach was steadily eroding this tendency by not reporting the numerical results but by providing interpretation of the figures, a critique of the experiment and proposals for the future direction of an investigation: gradually there came about an idea that the Research Department had a contribution to make in this respect.

Another difficulty with BH rails was becoming apparent; this was the occurrence of cracks in the upper fillet radius, that is immediately under the rail head. These cracks ran longitudinally, usually from the rail end, and if not detected early by the lengthman could extend in such a manner that a portion of the rail head became detached. Use of the FB rail offered an improvement since a rail section like the 110 lb/yd FB was higher, and had a thinner web; these two factors could make it possible to have both a stronger fishplate and a larger radius under the head. This subject was ideally suited to study by photoelasticity using models of the cross section; a number of such tests were made by Newberry resulting in an improved rail section for the 109 lb/yd rail the Civil Engineer was developing. However an inevitable effect of this attention to fillet radius was the reduction in web thickness and an increase in the wedging force exerted by fully tightened fishplates which was shown, later, to cause excessively high stress in the web. This episode exposed the danger, in experimental stress surveys, of looking at the object in only one direction; but in any case no suitable method of studying web stresses existed at that time.

Trial lengths of 110 lb/yd FB rail were now being rolled and installed in the track; this revealed that there were development problems particularly of manufacture and fit in the design of ordinary fishplates and junction fishplates. The design of the baseplate, which replaced the chair, and the rail fastening were also in question. In all of these matters the Engineering Section and Charles Loach were involved.

Meanwhile there was renewed interest in the possibilities of welding rails into longer lengths following the publication of an article in a Continental journal in which it was suggested that a long rail, of a few hundred feet, securely fastened to sleepers, would not experience the expected overall expansion or contraction with change in temperature but would instead be put into compression or tension, only a relatively short length at each end changing in dimensions. This was to be investigated and Loach devised an experiment in which a 300ft rail firmly fastened down was compared in length with 30ft lengths secured at one end only and otherwise free to expand or contract, the temperature being monitored. The results obtained entirely supported the theory and thus cleared out of the way one of the principal difficulties facing the concept of long welded rails. There were of course many more practical problems to be overcome before this objective could be secured.

The next problem to be considered was the possible use of concrete sleepers in place of the traditional softwood timber sleepers. Supplies of timber sleepers were normally imported from the

USSR or from Canada, but once war had broken out these sources of supply were interrupted or severely restricted and alternatives had to be discovered; of these concrete sleepers seemed the most promising even though there was almost no practical experience of them. The Civil Engineer took the initiative and ordered a batch of reinforced concrete sleepers from a supplier of structural concrete. These were laid in a branch line but the experiment was disastrous. The sleepers were extremely heavy and difficult to handle but in addition they rapidly cracked and had to be removed. It was obvious that something more than a simple empirical approach to reinforced concrete design was required. Dr Johansen took this point and began to develop rational design procedures; meanwhile arrangements were made for pre-stressed sleepers to be produced to a design in which the Building Research Station was involved and these were subsequently installed at Cheddington. Measurement of stress in the sleepers was carried out by Loach using scratch extensometers and at the same time the sleeper to ballast force distribution was determined by the BRS using a system in which hard steel balls transmitted the sleeper force via calibrated steel plates to the ballast. The load on the balls caused indentation of the steel plate resting on the ballast, the force involved being determined by measuring the diameter of the indentation as in the Brinell hardness test. The combined results of these tests helped Johansen to advance further his design criteria and specification for prestressed concrete sleepers leading to the manufacture of the Class E sleeper and the subsequent mass production of Class F and Class G sleepers in BR days.

But other results of the Cheddington tests convinced both Loach and Dr Thomas of the BRS that another important factor in determining sleeper loading of the ballast and rail end stress was the stiffness of both ballast and the underlying formation. This concept in turn led to ideas for the design of earth pressure cells which could be buried at different depths in the formation to measure stresses in the soil and to determine the mechanical strength and elasticity of the various soils likely to be encountered. These ideas were in fact parallel to those of A H Toms on the Southern and resulted, after the war, in a tripartite comparison of pressure cells at Orpington, Southern Railway, advantage being taken of a blanketing operation there. Two of the three types of pressure cell used strain gauges in a dynamic role; the third, provided by Dr A C Whiffin of the Road Research Laboratory, used quartz piezo-electric crystals. The tests were made as a locomotive passed over the site at various speeds up to 80 mph. The tests were extended all through the night by the incapacity of the Derby team to record from more than two gauges at a time and by failures in the Ashford equipment, whereas the RRL apparatus using a number of pen recorders performed with great satisfaction, a fact duly noted by the railwaymen. However the most important aspect of the tests was that a first, rather faltering, step had been taken on the road of research into the dynamic strength of soils.

Another line of research opened when the Civil Engineer, concerned by the reports of high rail end stresses at dipped joints and by the number of fatigue failures in rails reported by the Metallurgy Section, asked what was known of the fatigue strength of rails. In fact little was known at that time except for data obtained by Baldwin on the small Wöhler machine on which small machined specimens of rail steel had been tested and had shown a fatigue strength of +/-25 tons/sq inch which no one took as truly indicative of the full size rail. Unfortunately there was no machine available which could test a full size rail; the job of designing and producing a suitable machine, quickly and cheaply, was given to Cyril Maskery, known for his ingenuity with electro-mechanical devices. He decided to use the resonance principle, attaching a rotating out-of-balance mass to a simply-supported 15ft length of BH rail. As the rotational speed increased and approached the natural frequency of the rail, strong vertical vibration of the rail occurred which induced stresses sufficiently high to fracture the rail after some thousands of cycles of stress. Control was effected by the feedback system used on the Haigh testing machine (and also on the speed control system of the MTUs). The completed machine appeared to consist of a collection of electric motors, variable resistances, and Meccano gear trains all mounted on “bread boards” lying on the floor. However it worked exceptionally well for many years and once built quickly demonstrated that the fatigue strength of new as-rolled 95lb/yd BH rail was +/-11 ton/sq inch, less than half the figure for small specimens. Tests on rails which had been in track and exposed to wear and corrosion showed the strength to have further reduced to +/-9 ton/sq inch, a value which brought a certain cold realism into discussions on the permissible stress in rails in service.

At this stage it is also worth noting that Maskery designed and produced a train speed recorder for use on track which worked independently. This apparatus measured the time taken for the leading wheels of a train to pass two track switches installed 120ft apart on one rail. For each train passing it translated the time of passage into miles/hour and printed out, on a paper roll, the speed, the time of day and the date; it could therefore be left in track unattended for days. It was a marked advance on the previous and traditional method, which required two men, one large white handkerchief and a stopwatch.

So far there has been no mention of the other main interest of the Civil Engineer – underline bridges. For these, established procedures of repair, maintenance and eventual renewal existed and were rigorously applied up to the war years. After the war commenced and for several years after its conclusion this procedure could no longer be applied in full and the Engineer became concerned about the load carrying capacity of some of the older bridges. There developed therefore a need to know something about actual stresses in bridges and their resistance to fatigue, but this came about after the formation of British Railways and is described in later chapters.

Two years after the cessation of the war it was clear that the LMS would come to an end and obviously doubt hung over the future of the LMS Scientific Research Department. In looking back from 1947-48 to 1933 it was clear that relations between the Engineering Division and the Chief Civil Engineer had developed most satisfactorily. A partnership had grown in which there was mutual respect and soundly based collaboration on both the long-term strategy of moving towards a fundamentally different track structure and on the short-term tactical approach of experimentation on details.

Chapter 8: The LMS Research Department at Work - Metallurgy and Physics

The original plan for what became the Metallurgy Section was probably devised by Sir Henry Fowler about 1930. It envisaged its primary duty as supporting the LMS Works and the metallurgical operations therein. This may now seem surprising but it is necessary to remember the importance of the "black shops" in the Works at that period. Up to 1933 Crewe was still producing its own open hearth steel for boiler and frame plate, and forging blooms and tyres (as well as rails). It also had a large steel foundry, and an even larger iron foundry which produced cylinders, superheater headers, blast pipes and chimneys and hundreds of smaller castings including all the rail chairs for the Permanent Way. In addition there was a brass foundry and all the facilities required for forging, drop stamping, spring making, heat treatment and casehardening. Horwich, which also had a steel foundry, was perhaps second to Crewe in the extent of the metallurgical operations performed, but all the other Works had iron foundries and equipment for the forging and heat treatment of steel. There was therefore a very considerable investment in metallurgical operations which supplied more than half the material and semi-finished products required for the construction and repair of locomotives and rolling stock. In addition, the use of welding was growing rapidly in all the Works by 1933. Initially then, the role of the metallurgists in the Research Department was expected to be the supply of technical guidance for and the control of metallurgical operations such as foundry moulding practice, metal melting procedures, and the development of welding methods. However by 1933 metallurgists had already been appointed locally at Crewe and Horwich under E Millington, the Chief Metallurgist, who later proceeded to create similar positions at Derby and Glasgow. As a result, when the new Research laboratories at Derby were nearly complete (in late 1935), it was suddenly decided that these Works Metallurgists should be transferred to the control of the respective Works Managers and that their technical supervision should be vested in a Chief Works Metallurgist based in the CME Department headquarters at Derby, a post that was filled by A H C Page. By this means the CME, now W A Stanier, avoided the situation in which some vital workshop operations were controlled by staff from another Department.

At the inception of the Research Department in 1933, when Millington was designated as its Chief Metallurgist, he was supported by E D Knights, transferred from the Chemistry Division, by J Bradley, recruited from ICI, and of course by his team of works metallurgists. However, Millington was not a trained or qualified metallurgist; although experienced in some aspects of Works metallurgy he was unable to make any real technical contribution. It was clear that the new Section needed further technical strength and this led to the invitation to Dr Hugh O'Neill, then a lecturer at Manchester University, to join the Section in July 1934 with the title of Research Metallurgist. Working initially as assistant to Millington, his research activity became independent when his team moved to the new laboratory in November 1935 leaving the works metallurgists behind in the Locomotive Works. At the end of the same year, Millington retired and O'Neill succeeded to his title of Chief Metallurgist. At this stage J Dearden, who was Works Metallurgist at St. Rollox Works, Glasgow (and who had been trained at Horwich), was brought in to the Metallurgy Section and began a most useful collaboration with O'Neill.

The new Section still had some connection with Works metallurgy, principally in the role of a consultant when so invited, and also carrying out research on difficult long term problems such as improvements to the refractory linings of steelmaking furnaces and on the development of welding processes. Apart from this the scope was quite limited as the CME Department was certainly not interested in metallurgical research. As Dearden has written: "If a component wore badly it was replaced; if it broke in service it was made heavier and stronger. Failure by fatigue was regarded as death by natural causes". Stanier broke entirely new ground for LMS engineers by asking the Research Department to investigate a specific fatigue failure problem (fracture of locomotive tyres, see Chapter 6).

However, O'Neill made a rapid impact on the CME Department by his tests and proposals on alternative steels for coupling and connecting rods. The LMS had always used very ordinary plain carbon steels for these components; even when the forgings were heat treated their properties were not greatly enhanced. But on the LNER Gresley was using high strength nickel-chrome "Vibrac" steel for these parts. It was expensive but was also 30 to 40% stronger and much tougher than ordinary carbon steel. Maunsell on the Southern also used a similar nickel-chrome steel: in both cases the reduction of mass meant smaller reciprocating and rotating forces. O'Neill studied the relative merits of different steels and proposed the use of three new steels, not so high in strength as nickel steel but less expensive and adequately tough, their improved properties being obtained by alloying with manganese and molybdenum or by having a very fine grained structure. With remarkable celerity Stanier agreed to the use of these new steels and they quickly became standard on the majority of the many locomotives of Stanier design built in ensuing years.

The Derby Drawing Office was also pushed by Stanier into the use of stronger steels to save mass. This began with the Class 5 locomotives in which a "low alloy high tensile steel" of 2% nickel was specified for boiler plates which could therefore be 1/16in thinner than usual. In addition other low alloy steels, either "Ducol" or "Chromodor", were used for the main frame plates. Unfortunately all of these steels, although perfectly satisfactory in normal use, proved very susceptible to cracking when welded. This was particularly serious in the case of the 2% nickel steel used in boilers, since all the rivetted lap joints were seal welded as were also the various stiffening pads mounted on the firebox backplate. Cracks developed under the welds, running into the main plate, a situation which could not be tolerated. The Metallurgy Section was called upon to investigate the cause of cracking and to advise on prevention. At the time this cracking was first detected Dearden had just joined the Division and he joined O'Neill in the investigation. The cause of the cracking was soon found – hardening of the steel by the localised heat of welding – and it was also found that preheating the joint before welding was a reasonable cure.

O'Neill was not satisfied with a solution to a particular problem and sought a more general answer to the questions relating to the welding of the low alloy steels. He and Dearden therefore carried out a lengthy research investigation into the part played by a number of elements that could be added to structural steel to improve its strength, indicating for each element the hardening effect it produced as compared with that of various levels of carbon content in the steel. This research finally resolved itself into a list of "carbon equivalents" for all the alloying elements likely to used. Publication of this data in a paper to the Institute of Welding was an extremely important event. The low alloy high tensile steels were just coming into general use in Industry and the problem of weld cracking was assuming serious proportions especially in the production of armaments, the war having now started. O'Neill and Dearden provided not only an explanation of the problem but also methods of avoiding it and, what was more important, a means of predicting when trouble was likely to occur if precautions were not taken. Their work was of international importance; many researchers in different countries repeated it and attempted to produce different and hopefully more accurate formulae for calculating the "carbon equivalent" of the various elements likely to be used, but it was found very difficult to better the original Dearden and O'Neill formula which still remains in regular use today enshrined in the current British Standard BS 4360 which deals with structural steels and the welding thereof.

The Civil Engineer began to make use of the Metallurgy Section's expertise early in its history, inspired perhaps by the Advisory Committee interest in rail wear and the need for classification of rail failures by type. Broken rails were sent to the Division for examination and after a few years a reporting system was devised and instituted for all cracked or broken rails. Clearly any such system needs to be in continuous use for two or three years before even tentative conclusions can be drawn; this was the case with rail failures, but once this initial phase had passed an annual statistical report was prepared. This proved to be of such steadily increasing value that it has been produced every year right up to the present time. A similar study of rail wear was also put in hand and here again a long delay had to be accepted before any reliable results were obtained – understandable when it is appreciated that plain rails may remain in track for 15 to 20 years before there is any need to change them for excessive head wear. For this study a number of sites having different traffic, climatic and environmental conditions had to be chosen and visited at regular intervals by Research staff who had to measure with considerable accuracy, and between trains, the amount of material lost through wear and corrosion. All this work on rails was masterminded and supervised by Dearden who possessed exactly the right characteristics of tenacity, patience and thoroughness to guide an essentially long-term project.

O'Neill, having initiated and completed valuable work on the welding of the alloy steels, having persuaded the CME of the value of a modern approach to the selection of connecting and coupling steels, having introduced the use of industrial radiography and set the investigation of the Civil Engineer's rail problems on a sound footing, began to look for fresh problems to attack. One of these was the very high cost of tin and copper used in the many plain bearings employed in locomotives and coaching stock at that time. Much of this money was lost during the machining of bearings to size for each vehicle and also when the bearings were scrapped, since the mixture of tin rich whitemetal and bronze was of little value compared with the cost of either of the metals in the virgin state. Bradley was put to work to devise a method of separation of tin based alloy turnings and scrap from those of bronze. A partly successful method based on the differences of melting point had been in use since Millington's day but a more refined procedure was required and eventually successfully developed and installed in Derby Carriage Works, only to fall into eventual disuse due to lack of workshop discipline in the initial manual separation of different types of bearing and later, of course, due to use of roller bearings.

After the war O'Neill turned his attention again to rail problems and particularly to those at rail ends where, because of the discontinuity in stiffness, the rails suffered wear and batter which only exacerbated the forces applied to the ballast and in turn increased the damage to the rail end. O'Neill's approach was to mitigate the problem by depositing harder metal on the rail ends by welding, and to attempt to produce duplex rails having a harder and stronger steel rolled integrally into the head area. He also experimented with corrosion layers in the rail head for rails laid in the vicinity of water troughs. However by 1947 O'Neill seems to have concluded that there were few difficult metallurgical problems left in an industry which was based predominantly on the use of cast iron, wrought iron, the simpler steels and nineteenth century types of non-ferrous alloys – or perhaps Academia was presenting a stronger attraction. In the event he took up the post of Professor of Metallurgy at Swansea University, leaving John Dearden to carry on the good work, particularly on rails.

Turning now to the Physics Section, we have seen in Chapter 2 that Trevor Eames emerged as Section Head after the initial M G Bennett regime of 1935. Eames carried the title Senior Physicist. He was established with his growing team in London, occupying space in St. Pancras Chambers on the fourth floor of the former Midland Grand Hotel, behind the ornamental balustrade. This was evidently intended to be a permanent arrangement: when the new Derby laboratory was specified, no allocation of space was made for Physics, and as built in 1935 the building accommodated only the Engineering, Metallurgical, Textiles and Paint Sections and the Library.

Eames set to work to build his team. By 1936, when he recruited a young physics graduate, Leslie Thyer, later to become his deputy, the team numbered six.

Throughout the pre-war years the biggest single subject of research was Eames' own first area of interest: the carriage of perishable goods. This reflects the importance to the LMS in those days of express freight trains carrying foodstuffs. Meat, both fresh and frozen, sausages, fish, dairy products, fruit, vegetables, even ice-cream are described. The science mainly centred on meteorology (expected outside temperatures), initial temperature of the consignment, quality and extent of insulation and the quantity of refrigerant to be provided. This was sometimes water ice but more usually "Drikold" (solid carbon dioxide). The latter was carried in a bunker insulated on five faces while the sixth face consisted of an aluminium plate whose area in contact with the Drikold determined the rate of refrigeration. Investigations led to some epic journeys by members of staff riding in guard's vans and monitoring the slowly rising temperatures of their charge. Trevor Eames himself is described accompanying a cargo of rabbits (in "Carry On", April 1949); and Douglas Wright recalls accompanying fish traffic from Ireland to London. For some traffics, the opposite consideration applied: certain oils and fats and ripening bananas had to be maintained by insulation above a certain temperature.

Other thermal studies lay within the Section's remit, for example the heating, ventilating and humidity control of occupied spaces. The Section gave advice for buildings, both hotels and workplaces, and for passenger rolling stock.

Associated with heating was lighting. Again the staff were involved, for buildings and for train interiors, with measurement and advice on lighting levels. Also for proposed new buildings, noise surveys were undertaken to determine the appropriate level of sound insulation.

Optical studies were particularly important for signal lenses, where the brightness and degree of focusing had to be determined and the colour controlled. At least by the 1940s, the quality control of signal lens colour was undertaken by the LMS Physics Laboratory for all the four main-line railways. Also with increased focusing the alignment of signal lights became more critical; Thyer later invented a device to facilitate this procedure.

With the outbreak of war in September 1939, the Physics Section was evacuated to Derby and was absorbed into the London Road laboratories, sharing space originally allocated to Textiles. Indeed Eames and Winson, the two Section Heads, shared an office on the first floor for several years. Probably both Sections were reduced in staff numbers due to calls to war service – at least four members of the Physics Section had been drafted away, and probably Textiles had also lost staff. The Physics Section was to remain in Derby thereafter.

To strengthen the team in the early war years, Douglas Wright, a physics graduate then working in the Paint Section, was transferred across and contributed to the thermal studies (including thermal effects in bearings) and other aspects of the Section's work. Recruiting became a possibility again in 1943, when Roy Bickerstaffe joined as a trainee, to serve with the Section for 41 years. Even so, his arrival brought the war-time strength of the Physics Section only to four, Eames, Thyer and Wright being the other three.

With the move to Derby, the content of the Section's work seems to have changed little. Thermal studies were prominent, with optical studies in second place. Environmental studies included measurement of dust and smoke concentrations. An acoustic capability was maintained, but was not much called at this stage. This would change greatly in the 1950s, with the advent of diesel locomotives and growing consciousness of the importance of workplace noise.

As with the Engineering Section, the use and development of measurement techniques were very important to the Section's work. Some of the instrumentation, although modern at the time, was quite labour intensive in use. For example, the tri-chromatic colorimeter of Donaldson's design, set up in the photometric laboratory, required the matching by eye of filtered reds, greens and blues, with five decisions by one operator and a second opinion by another. It was also difficult to maintain concentration, and breaks were necessary to combat chromatic adaptation of the observer's eyes. The sole item of acoustic instrumentation was a proprietary "loudness measurer" consisting of a calibrated 1 kHz oscillator (2 large triode valves), a precision attenuator calibrated in decibels, and a pair of earphones. The investigator adjusted the loudness of the tone in the earphones until it equalled the loudness of the subject noise observed with the earphones removed. Again several attempts and more than one observer were necessary, but with care a good measure of perceived loudness could be obtained.

Otherwise staff took pride in "the design and improvisation of their apparatus". A portable photometer was specially adapted to measure the very low light levels permitted out of doors during the war. Arrangements of thermocouples and "distance reading thermometers" were devised for the perishable goods work. A simple method of measuring dust concentration was devised (measuring the blackness of a spot on filter paper) to avoid the cumbersome thermal precipitator method. Laboratory arrangements were made to measure thermal insulation values at full scale for vehicles, containers and building components. Thyer designed a simple hygrometer to measure humidity: with the thermal insulation measurements, this was important just after the war in assessing novel construction methods proposed for "prefabricated" buildings.

A problem which occupied Thyer in the 1940s and continued into the 1950s was failure of the glasses in steam locomotive water level gauges. These glass sight tubes worked, of course, at the temperature and pressure of the boiler. They had a very short life (3 weeks in service was the starting point). Also a failure, if not adequately protected by the ball-valves provided, could be hazardous to the crew while they struggled to reach the manual isolating cock. (The locomotive could normally continue in service as gauges were duplicated and the failed glass would be replaced at the next shed visit). It was found that the glass of the gauge was attacked ("wasted") by the alkaline boiler water, quickly reducing its wall thickness to an unsafe value. The condensate was much less damaging, however, and Thyer soon proposed arrangements for connecting the gauge so as to retain the condensate composition in the gauge as far as possible, and avoid repeated ingress of boiler water. This reduced "wasting" of the glass tenfold. Thyer also attended to subsidiary matters such as random failures of unwasted glasses (mainly due to residual stresses in manufacture), test procedures for correct function, and visibility. He also studied the safety of windscreens.

From the very early days, mathematics had formed a part of the Physics Section remit. A mathematician, Jack Howlett, was a member of the staff before 1936. He was involved in both theoretical calculations and the statistical analysis of experiments. Early in the war he was constructing a mechanical differential analyser to solve differential equations and was drafted by the Ministry of Labour to continue his work at Manchester University. He returned for a time after the war. In those days a computer was a person (perhaps assisted by a hand calculating machine) rather than a machine. A Miss Burley was recruited from the Minerals Office – a great source of clerical staff – to fill this role, which she did, later with an assistant, until the advent of electronic computing in the late 1950s. With the Physics Section established in Derby, the statistical analyses and computing generally were provided as a service to other Sections of the Research Department. As with acoustics, this activity was destined to grow to exceed the scale of its parent, but not in the timescale of this chapter.

Chapter 9: The LMS Research Department at Work – Chemistry, Paint and Textiles

It cannot be claimed that the formation of the LMS Research Department brought great changes to the way of life of the Chemists at Crewe, Derby, Horwich and Glasgow, since their activities, which covered most branches of railway operation, continued as before under the general direction of Dr P Lewis-Dale. There were two organisational changes: firstly the Paints and Varnishes Laboratory, ex. Wolverton and now established in the Derby Carriage and Wagon Works, was formally incorporated as the Paint Section. In 1935 they were provided with a better home in the new Derby laboratory. Secondly, and perhaps in response to a criticism that any chemical research undertaken tended to get swamped by the mass of routine activities already described in Chapter 1, it was decided that a separate Chemical Research Section should be instituted. This was to be based at the Stonebridge Park laboratory, which had been taken over from the Chief Electrical Engineer in 1933. A Dr W A Macfarlane was appointed to the post of Senior Research Chemist in 1938, and in 1939 V Binns and S Bairstow were transferred from the Crewe laboratory to form the nucleus of the research team. However little record survives as to what work was done in this phase, and in December 1943 Stonebridge Park reverted to being a normal Divisional laboratory, with Bairstow as its Head.

There was also intended to be a policy of scientific specialisation for each of the laboratories, but this seems to have depended upon the particular enthusiasms of the Area Chemist. Wolverton's specialism and its translation to Derby has been mentioned; two others are noteworthy. Hayhurst at Horwich made a special study of entomology and infestation, and became so expert that in 1943 he was put in charge of a new section – Disinfestation – and set up a laboratory at Hunts Bank near Manchester. The subject may seem a surprising one for a railway but it must be recalled that in those days it was often the railways that received, in their own docks, for general distribution, food stuff cargoes from all over the world, often accompanied by exotic fellow travellers. Railways also owned and operated warehouses for a wide variety of products and these, particularly when used to store food grains, attracted pests and parasites. Hayhurst made a great success of Disinfestation; like every other aspect of railway research it covered an extraordinarily wide field from LMS Hotels downwards: in addition his opinions and comments were widely sought and valued by other organisations such as shipping companies.

Dr Lewis-Dale, the Chief Chemist, together with Bairstow and Binns from Crewe developed in the 1930s an interest in combustion, associated with the great attention then being given to locomotive performance. As already described in Chapter 3, methods were found to analyse the gases in a locomotive smoke box and to use this data to determine the efficiency of combustion and the heat lost by exhaust gases. Possibly due to the observations made in the course of this work it was noted by the chemists that, for any given type of locomotive and value of trailing load, the rate of steam consumption tended to be constant; steam production should therefore be constant. This could be brought about by regular firing at a certain rate of shovelfuls of coal every two minutes that the locomotive was working. Instrumentation was devised based on blast pipe pressures to show the fireman what rate of firing, e.g. 5 shovelfuls every 2 minutes, was required to provide the steam needed. An educational programme for firemen was set in hand, but like many other projects it foundered in the wartime conditions.

It was perhaps this enthusiasm for combustion efficiency which led Bairstow to develop apparatus for making producer gas for use in internal combustion engines two years before the outbreak of war. Some twenty cartage lorries were equipped and in service: the system was taken over by the Ministry of Transport and applied to some buses. The lack of wider use was probably due to the problem of engine maintenance due to the deposition of solid sulphur and sulphur compounds within the engine.

The subject of water softening was re-examined: systems were developed on the base-exchange principle, and installed. Satisfactory operation was ensured by setting up a small team of chemists under Hancock to supervise the operation of the softening plants.

Another activity was a closer study of the principles of lubrication, taking the subject forward from the position described in the fifth and final edition, published in 1927, of Archbutt and Deeley's classic book. Pioneering work was done on the role of viscosity which showed the advantages, particularly when applied to motorised cartage vehicles, of mixed and lower viscosity lubricants which gave easier starting under frequent stop-start operations as well as fuel economy. The addition of 10% rape oil to wagon axlebox oil also became standard practice: it produced a small amelioration of the perpetual wagon hot-box problem.

In 1938 Dr Lewis-Dale retired and was succeeded as Chief Chemist by W P Henderson.

During the war the Chemical Section inevitably became involved in Air Raid Precautions, particularly the possibility of gas attack. The Section organised major exercises at Depots and Works on precautions against gas, antidotes and indicating paints. During this period the traditional work of railway chemists was modified by new problems: new types of freight including thousands of tons of explosive, for example.

After the war the chemists returned to their customary work, and although that may seem dismissive, the value of that work to the LMS system remained as high as ever and should not be decried because no outstanding new development is to be recorded on these pages.

There were two other new Sections formed in 1933 by Sir Harold Hartley to which reference must be made. The first for consideration is undoubtedly the Paint Section. As we have seen, this originated at Wolverton under F Fancutt's energetic leadership and had been transferred to Derby in 1930 where it was rapidly expanded, eventually to 24 staff. With its new status within the Research Department, and still under Fancutt's leadership, the Section continued with great enthusiasm and appears to have laid claims to a very wide field covering all aspects of the condition of metallic or wooden surfaces before, during and after the application of protective films. Obviously they were concerned with the quality of paint supplied and carried out regular checks on deliveries: equally they were interested in the development of new formulations and their effects on applicability, correctness and fastness of colour and durability of paint film in the broadest sense. Painted surfaces lived in a harsh environment on railways subject to sunshine, ultra-violet light, adverse weather, smoke, oil and grease. Not least was the erosion by showers of brake block dust and the ash particles smelted by the chimneys of steam locomotives, both of which impinged at high relative velocity on the gleaming sides of coaches. But in addition there was the problem of cleaning, particularly of coaches, which was of considerable importance commercially. Cleaning had to be done quickly – usually overnight in carriage sidings and by unskilled carriage cleaners – and it had to reveal the undamaged brilliance of the paintwork without, if possible, attacking the paint film or seriously shortening its life. When locomotives or coaches had a major repair in Works, old paint was removed, so there was a need for a paint stripper, quick in action, not unkind to the base material or to the bodies of the men applying the stuff.

Life of paint was a continuing problem; once the Section was in the new laboratory a "weatherometer" was purchased from the United States. This was a machine which alternately exposed panels coated with the paints under test to ultra-violet light, to some radiant heating and then to a tropical rainstorm and continued to do so for whatever period of time was required.

The Paint Section became equally concerned with interior treatments. In the mid 1930s they were actively concerned with the development and application of flame resisting or retarding varnishes for interior woodwork in carriage construction and this long before any other transport undertaking had considered the problems. The Section was also concerned with the mechanism of corrosion and the development and suitability of protection methods for exposed steelwork, buried steel pipes, etc. In this they co-operated with S C Britton, a member of the Metallurgy Section, who did excellent work on the physics of corrosion. Not all corrosion problems (rails for example) were solvable by paint treatments.

In these early years there were no standard methods (or indeed any methods) for measuring the basic physical properties of paint films, such as thickness, tensile strength, elasticity, hardness, permeability and so on. The Section accordingly set about developing such methods, and in collaboration with the Paint Research Station and the British Standards Institution worked these up into national standards.

During the war, the work of the Paint Section was important to the war effort, and was accordingly given "reserved occupation" status. The short life of coatings on ships was a particular problem, being only about a year at the outset. Apart from corrosion, the growth of barnacles was a serious problem, slowing the ships and increasing their fuel consumption. Working closely with the Iron and Steel Federation the Paint Section tackled this problem so effectively that the life of paints was increased by three or four times. They also developed mustard-gas detecting paints that changed from yellow to bright red – fortunately not required – and developed a blue coating for carriage interior lights to meet the black-out regulations.

With so many lines of work vigorously pursued it could be asked how long the supply of problems persisted in view of the energetic attack. The answer is, of course, that the same problems still exist today. Everything the Paint Section did successfully was an immediate but only a partial solution. If a new carriage painting schedule demanded a complex system of 20 coats of paint and varnish, which would survive for 10 years it immediately posed the new problem: by how much could the weight of paint applied to a vehicle (and the cost) be further reduced, and could the life be extended to, say, 15 years? The obvious final objective for the paint researchers is to discover a paint capable of being applied rapidly, one coat only, which dries instantaneously and lasts forever! Continued striving to reach new objectives is the hallmark of good industrial research.

Textiles was not a new Section in the sense that Metallurgy was in 1933. Long ago a clerk in the Stores Department became interested in carrying out tests to see how well the ropes and brushes purchased for the LNWR satisfied the ordering requirement. He persuaded his superiors to provide a room near Euston and some test equipment which was already becoming standardised because of the British interest in the export of textiles and allied products. Eventually this work was taken over by two brothers, first within the Stores Department and eventually transferred to the Scientific Research Department directed by Hartley and managed by Herbert. As always happens when a good service is provided the demand increases: the demand extended to include uniform clothes, coarse for porters, warm for train crews and superior for station masters of different levels. Samples of these cloths were tested for strength, colour and colour fastness, quality of thread, number of threads per inch and only then released if satisfactory to be made up into uniforms. The same treatment was given to carpets, to upholstery materials for first and third class compartments in coaching stock and to sheets, blankets and pillow-cases for the LMS Hotels. This superior class of work pushed into the background a smaller but never extinguished workload on haulage and capstan ropes, brushes of every conceivable class for sweeping, lubricating, cleaning and painting, and on wagon sheets, where co-operation with Paint Section began. Textiles Section concerned themselves with the make up of strong, tough and waterproof canvas sheets, duly eyeletted for securing (by tested cords) over the contents of "open" wagons. Paint Section devised wagon sheet dressings to improve their impermeability and strength. But whereas the work of Paints contained a considerable proportion of development work, Textiles had to accept a life of wholly routine testing against LMS and BS specifications – routine, but routine work in a very well-found laboratory equipped with large standard textile testing machines. But it was not large in terms of personnel; perhaps two scientists, probably chemists, and three young ladies adept at the standard tests on "material".

The two brothers were succeeded by W Pritchard who in turn retired at the end of 1945. He was followed by C G Winson, who was destined to move his Section, with the Physics Section, from the Research Department building in London Road to Cavendish House near Derby Station in 1951. The decision to purchase and adapt this building was made in the years of London Midland Region management in 1948, although the move was completed under the Railway Executive's Research Department management in 1951, as we shall see in chapter 11.

Chapter 10: The Formation of British Railways' Research Department

Nationalisation of the railways took place on 1 January l948, when the British Transport Commission was formed, one of its components being the Railway Executive. This was the managing body for British Railways, formed from the four mainline companies LMS, LNER, GWR and Southern, and now re-arranged into six Regions. The other four Executives of the BTC were: Docks & Inland Waterways, Road Transport, Hotels, and London Transport. The first Chairman of the BTC was Sir Cyril (later Lord) Hurcomb. Sir Eustace Missenden, previously General Manager of the Southern Railway, became Chairman of the Railway Executive with R A Riddles as Member for Mechanical and Electrical Engineering, Road Motor Engineering and (for a time) Scientific Research.

The l947 Transport Act required that the Commission should conduct such scientific research as was appropriate, ensuring the availability of the necessary staff, facilities and equipment. It was also required to seek the approval of the Ministry of Transport for the direction and type of research that it proposed to undertake. Sir Cyril Hurcomb was punctilious in observing all the requirements of the Act; he therefore appointed a Committee under the chairmanship of Sir William Stanier, then aged 71 and retired from railway work, to enquire into the nature and extent of the research then in hand within all the Executives of the BTC, the staff and facilities available, and to make recommendations for the organisation of research in the future.

Initially Stanier's committee circulated a questionnaire designed to reveal what research and testing were being carried out, and with what equipment, in the new Executives. This included the six Regions of British Railways which were managing for the time being the research activities they had inherited from the former companies, and which continued without any obvious interruption. All replied in an "anxious to please" mode, most claiming deep involvement in research and development, except for the Road Transport Executive which was at that time heavily involved in organisation and the acquisition of road haulage companies and vehicles.

The committee now began a series of visits to the various laboratories and installations. These quickly revealed that the majority of claims to important research work in hand were based on very ordinary routine testing work done without dedicated staff, equipment or premises. The practice of research and the use of scientific method were found to be limited to the old LMS Research Department (now mostly under London Midland Region management), to the chemical laboratories of the other three main-line companies, to the laboratory of London Transport and finally to the Physical Laboratory of the Southern at Ashford and the Soil Mechanics laboratories at Wimbledon and Paddington. There were of course Metallurgical Laboratories and Test Houses, but these existed to provide a specialised routine service to the Works in which they were situated. Most Regions also had some facilities for locomotive testing, ranging from the mere possession of "indicators", through dynamometer cars to the full glories of the Rugby Locomotive Testing Station – all of which were regarded strictly as the perquisites of the Regional CMEs which should never come under the control of some future Research Department.

Stanier's committee worked rapidly so that by 1 November 1948 a report was ready. It recommended the consolidation of the research effort into two Research Departments, one within the Railway Executive and one in the London Transport Executive. The Railway Executive Research Department as proposed was effectively an extension of the LMS Research Department, achieved mainly by taking over all the chemical laboratories which had belonged to the other major railways to form an enlarged Chemistry "Division"; the Ashford Physical Laboratory was also taken in and formed an adjunct to the Engineering Division. Soil Mechanics laboratories remained the responsibility of their major user, viz. the Chief Civil Engineer. This meant that the Wimbledon laboratory had to split into two parts, the chemical and building materials part joining Research, subordinate to Stonebridge Park, while A H Toms' soil mechanics and instrumentation sections remained with the Southern Region CCE. In line with the Stanier proposals, the Railway Executive's

Research Department was also given the remit to provide research effort “on an agency basis” to the Docks & Inland Waterways Executive and to the Hotels Executive. The LTE Research Department had the corresponding remit to serve the Road Transport Executive.

There were other important recommendations. It was proposed that the BTC should appoint a Chief Research Officer to promote and oversee the research activities of all the Commission’s Executives, and also that two new Committees including eminent external scientists should be set up at BTC level. The first was to be called the Research Advisory Council and was to have duties identical to those of the previous Advisory Committee on Scientific Research of the LMS. The second body was to be the Research Co-ordination Committee, which was to ensure that each of the Executives was made aware of all important research conducted within the Commission, in order to avoid duplication, and to encourage use of the results from internal research and from the various DSIR Research Associations to which the BTC subscribed. Finally, the Stanier Committee was very clear in distinguishing between research and development. It recommended that Design and Development Sections of the Technical Departments of the Railway (and London Transport) should be “considerably strengthened” to take developments forward.

In May 1949 Dr H E Merritt, previously Research Director of David Brown Ltd and a world authority on gears and gearing, became the first Chief Research Officer of the BTC. In the same year T M Herbert was appointed Director of Research for the Railway Executive, now reporting directly to the Chairman, Sir Eustace Missenden, in line with the Stanier proposals.

Neither of these was a particularly happy appointment. Herbert had years of experience and some success in building up a viable research department on the LMS: while officially reporting to the Chairman he received little support from Riddles who felt no great sympathy or need for engineering research and studiously avoided any public mention of the Research Department. But Herbert was also to a degree subordinate to Merritt, a scientist who had everything to learn about railway problems. On the other hand Merritt soon found that almost no research activity existed on any of the other Executives except London Transport and that had only the traditional railway type chemical laboratory. Admittedly the ex-LMS Hotels had from time to time drawn on the assistance of the Chemists and had regularly also used the Textiles Division, practices which they proposed to continue; similarly the ex-LMS owned Canals and Docks had simple testing done by the Engineering Division but as for engaging in research they saw little need. Merritt therefore found himself to be a king without a kingdom, except for one province from which he was fairly excluded by the local prince. Nevertheless he made some progress in promoting research by the publication of Transport Research Quarterly (although this closed down in 1952) and particularly through the meetings and activities of the Co-ordination Committee. But it was still an unsatisfactory position from which Merritt resigned in 1951. He was replaced by C C Inglis who was formerly Deputy Chief Engineer of the Armament Design Establishment.

Meanwhile T M Herbert, following his appointment as Director of Research in 1949, spent the next year and a half in organisational matters in readiness for the formal setting up of BR Research which was due to take place on 1 January 1951. He devised an organisation of six “Divisions”, strongly reminiscent of the LMS’s Sections, but with the Paints Section re-absorbed into the Chemistry Division (this was a late adjustment) and with a new Division added: Operational Research. The new Divisions – Chemistry, Engineering, Metallurgy, Physics, Textiles and Operational Research – were very unequal in size; nevertheless all Divisional heads carried the title of Superintendent. Herbert’s preparatory work included some disentangling of metallurgical responsibilities on other Regions, such as had been arranged on the LMS fifteen years before. Then certain senior appointments had to be made, for example for the head of the new Chemistry Division which would be nearly twice the size of the LMS Chemical Section and clearly demanded a strong leader capable of welding all the laboratories into a reasonably harmonious whole. Herbert had been impressed by the performance of F Fancutt as head of the Paint Section and decided that he should be the new Chemistry Division Superintendent. There was in fact a Chief Chemist, W P Henderson (ex LMS), still in post, but he was persuaded to return to the Horwich laboratory, which he had previously run for ten years, as the Area Chemist. Fancutt was duly appointed Superintendent, the now subordinate position at Protective Coatings, successor to Paints, being filled by F G Dunkley.

(Fred Dunkley had been one of the original team of five that had moved with Frank Fancutt from Wolverton to Derby in 1930.) There was however another difficult problem in the person of Thomas Henry Turner, Chief Chemist and Metallurgist, E & NE Regions. He had held this same position on the LNER and claimed a close relationship in the past with Sir Nigel Gresley. T H Turner was sufficiently senior to have a very strong claim to the post of Chief Chemist, BR, but he had very many outside technical interests, lacked the confidence of the post-Gresley CMEs and was barred from access to the Eastern Region Works. Herbert remained adamant that Fancutt should become "Chief Chemist", but a senior position had to be found for Turner. In the event it was decided to place Turner in the position of Superintendent of the Metallurgy Division, a post which, when occupied by Dr O'Neill, had carried the title of Chief Metallurgist. Here again there was a sitting tenant in the person of John Dearden who had been appointed to the post to replace O'Neill in 1947. However, a neat if temporary solution was found thanks to the formation in 1950 of the Office for Research and Experiments (ORE), a subsidiary of the Union Internationale des Chemins de Fer (UIC). ORE was based in Utrecht and was intended to be staffed on the basis of having engineers or scientists from member railways seconded to it for a period of one or two years. John Dearden went to Utrecht in February 1951 and became a foundation member of ORE and the first British "Conseiller Technique" at Utrecht, thus giving T H Turner the opportunity to accustomise himself to his new role. Dearden's substantive post meanwhile was Assistant Superintendent of the Metallurgy Division.

There were no more difficult senior appointments to make, although one important name is now missing from the lists. Dr. F C Johansen had left the Department late in 1949 to take up the post of Director of Research with the W & T Avery group of companies. Tom Baldwin had succeeded him as head of the Engineering Section, the post which Johansen had held with distinction for 17 years. In fact the three year interregnum following Nationalisation seems to have been an unsettling time for staff; in 1950 T M Herbert expressed concern at the loss of "more than a dozen" qualified staff during the period. Nevertheless on 1 January 1951 the new British Railways Research Department duly came into existence with the organisation and senior staff as shown below:

Headquarters			
Director of Research		T M Herbert	London
Assistant Director of Research		E Morgan	London
Personal Assistant to Director of Research		N A Merriman	London
Librarian		Miss M Hastings	Derby
Assistant Librarian		Mrs B G Gaukrodger	London
Chemistry Division			
Superintendent		F Fancutt	London
Assistant Superintendent		G H Wyatt	London
Assistant Superintendent (Protective Coatings)		F G Dunkley	Derby
Area Chemists:			
Doncaster	(ex LNER)	A McFadden	
Stratford	(ex LNER)	E D Henley	
Derby	(ex LMS)	S Bairstow	
Crewe	(ex LMS)	G E Wilson	
Horwich	(ex LMS)	W P Henderson	
Stonebridge Park	(ex LMS)	E A Coakill	
Darlington	(ex LNER)	A Winstanley	
Glasgow	(ex LMS)	E A Morris	
Wimbledon	(ex SR)	K F A Linton	
Ashford	(ex SR)	W Blyth	
Swindon	(ex GWR)	R W Dawe	
Engineering Division			
Superintendent		T Baldwin	Derby
Assistant Superintendent (Derby)		J C Loach	Derby

Assistant Superintendent (Ashford)	B R Byrne	Ashford
Metallurgy Division		
Superintendent	T H Turner	Derby
Assistant Superintendent	J Dearden	Derby
Physics Division		
Superintendent	T A Eames	Derby
Assistant Superintendent	L Thyer	Derby
Textile Division		
Superintendent	C G Winson	Derby
Assistant Superintendent	S Ashcroft	Derby
Operational Research Division		
Superintendent	M G Bennett	London

The new BR Research Department numbered a little over 300 staff of whom some 70 were professionally qualified. Although larger, it was clearly set on the path laid down by Sir Harold Hartley in 1933 but with one new feature as we have seen – the inclusion of an Operational Research Division based in London. This reflected the great impression created by the publication, after the war, of accounts of the successes achieved by Operational Research techniques in the anti-submarine and anti-aircraft war. The BR unit was composed of a small number of mathematicians and statisticians, and great stress was placed by Herbert on the bringing of scientific technique to bear on "non-technical problems", i.e. on the use rather than the engineering design of equipment. At the outset the unit's remit was very broadly drawn – perhaps too broadly – to include human factors, use of physical assets, public relations (in the sense of social surveys and assessments of demand), planning, joint transport problems, and economic and physical indices of efficiency. Indeed in the early years some attention was given to subjects such as psychology and ergonomics, but experience and hard commercial reality soon caused effort to be concentrated into the use of assets category and the economic consequences of operational decisions and procedures. The unit was housed in 20 Euston Square, shared with the headquarters of the Chemistry Division. Herbert and his small team meanwhile had moved to 222 Marylebone Road, the headquarters of the Railway Executive.

Chapter 11: BR Research – The First Five Years

The weeks following the birth of BR Research brought few changes to the work of the laboratories; nor could great changes have been realistically expected. The Officers of the Railway Executive saw their primary duty to be to restore the railway system to its state of 1939, with improvements of the kind likely to arise from normal development. For the Mechanical Engineer, this implied steam haulage of rolling stock and in 1951 this type of motive power and coaching stock was being built, albeit to new standard designs. The extension of electrification to main lines was foreseen, and indeed electrification schemes for Manchester-Sheffield-Wath and for Shenfield-Liverpool Street, both planned pre-war with overhead lines at 1500V dc, were actively in hand. Diesel traction was also foreseen and both LMS and the Southern had ordered one or two Diesel locomotives just before nationalisation. Further developments were expected to be solely within the province of the Chief Mechanical Engineer of the day. Technical assistance would come mainly from the equipment suppliers: the Research Department would only be required to help from time to time with problems such as fatigue failure of components.

The Signal Engineers' views were very similar. A programme of installation of multi-aspect colour-light signalling controlled by track circuiting was in hand, coupled with the use of electric interlocking, miniature lever frames and power operation of signals and switches. Any technical assistance or development required came from the suppliers; the Signal Engineers saw no prospect of using the Research Department.

Fortunately the situation was entirely different in the case of Civil Engineers as has been described earlier. Programmes of work aimed at developing a stronger rail section, at the eventual use of concrete sleepers and at reducing the number of rail joints (by welding if possible) existed with strong Research involvement in the experimental work. Under the new regime the Civil Engineer intended to increase the rate of progress. In addition to the load of Permanent Way work, the Bridge Engineers were also becoming concerned with the state of the older bridges, many already 100 years old and usually made of wrought iron. There was therefore a need for measurement of stresses in bridges, for some advice and assistance on fatigue, and for analysis of loads and stress systems in new designs. The Civil Engineers were clearly making growing demands on Research capabilities.

There was also another source of largely unplanned testing and research. This was from the network of Inter-Regional committees set up by the Railway Executive early in its history, having recognised that any attempt to achieve a unified nationwide railway service depended upon obtaining a considerable degree of standardisation of working methods, equipment design and procedures. This was a major challenge because each of the six large railway Regions which now formed BR contained some serious differences in practice from the others and indeed had still not wholly assimilated internal differences inherited from the many pre-1923 railways. It was therefore logical to set up a number of committees on which each of the Regions was represented, often also including London Transport, under a carefully selected Chairman. The principal committees were of course those senior and permanent bodies such as the Civil Engineering Committee, the Mechanical and Electrical Engineering Committee and others charged with the determination of policy for major Departments. These were followed by their immediate sub-committees, such as the Permanent Way Sub-Committee, the Locomotive Design Committee, the Carriage Standards Committee, etc. Below these came the serried ranks of short-term ad-hoc bodies intended to discuss one or more specific problems before being dissolved. In many cases progress within committees was painfully slow because of the diverse but extremely strongly held views of the members. The descendants of Isambard Kingdom Brunel, for example, were not readily converted to methods practised in ex-Midland Railway territory!

The more wily Chairmen often found that ways through these impasses lay in proposing experiments or comparative tests of different pieces of Regionally-owned ironwork, or in obtaining a second well-informed neutral opinion. Inevitably both of these ideas eventually involved the Research Department since it possessed the apparatus, the scientific knowledge and in theory the time to devote to such matters. Committees usually began by prescribing the precise nature of the tests to be carried out, then slowly resigned themselves to the fact that research staff often saw things differently and perhaps more clearly, so that a research man would eventually be co-opted onto the committee. As an example, the Wagon Standards Committee instructed the Ashford Physical Laboratory (prior to the formation of BR Research) to make strength tests on different Regional designs of wagon. The Ashford Laboratory injected their own ideas on test methods which cast a whole new light on the forces applied to wagons in service and initiated a long programme of work on the humble wagon within the new Research organisation. Some of this test work remained semi-official, i.e. not reported to Research headquarters until complete, but nevertheless continuously faced Herbert with a fully occupied, or an overloaded, staff and longer and longer delays in the production of reports. Also this extensive activity on standardisation did not impinge only upon the Engineering Division. Chemistry, Metallurgy, Protective Coatings, Physics and Textiles were all asked to bring their accumulated experience to bear on the generation of system-wide standards.

Early in 1951 Herbert organised a Research Superintendents Committee, which he chaired, as a communication link to keep the Superintendents in touch with each other while enabling him to tell them what was required of them and to keep everyone aware of the machinations of the Executive. Herbert was also able to report on his struggles with his two principal problems: the perpetual shortage of staff and the desperate shortage of accommodation. He was in fact impaled on the horns of a dilemma, for if he were able to obtain authority for more staff he would then have nowhere to put them.

Nevertheless some progress was soon made in the matter of accommodation since by mid 1951 alterations to Cavendish House near Derby Station, authorised earlier, were well in hand. This patrician building, dating from the nineteenth century, had been a private waiting room for members of the great Derbyshire Cavendish family and their entourage, when they travelled to and from Derby by train. It was decided to transfer the Physics and Textiles Divisions to Cavendish House, the work of both sections having been impeded for some time by lack of space. Preparatory work completed, the two Divisions moved in February 1952 enabling staff at London Road to breathe out and expand. Meanwhile four new posts had been authorised by the Executive but that in itself made little impression since there were still many unfilled vacancies within the Department. Moreover there was at that time a mini-boom in scientific research in private industry, and in the several newly nationalised industries such as Coal, Gas and Electricity; suitable graduates could easily find more lucrative positions than with BR, which suffered from low pay and bureaucratic recruitment policies. Individual Departments also had their hands tied by the new Advertising of Vacancies scheme pressed on BR by the TSSA Union. This scheme required all vacancies to be advertised to all BR staff before any action could begin on external advertising, thus effectively inserting a six-month's delay into the proceedings.

The Research Superintendents Committee had other things to discuss in addition to staff and housing. Two new committees came into existence: the first, under the chairmanship of E Morgan but including F G Thomas of the Building Research Station and two Civil Engineers and reporting to the Civil Engineering Committee, was to clarify the requirements of concrete sleepers. The second, under Eames, was to study the problem of the de-icing of conductor rails. Possibly more important than either of these was a report of the Department's mathematician who had attended a conference on Electronic Calculating Machines and was convinced that one might be an asset to research in a few years time. A discussion on the matters to include in a six monthly report to the Executive is instructive in showing how firmly wedded to steam the railway still was. Chemical Services were reporting on means of strengthening brick arches in locomotive fireboxes, and on their proposals for the systematic firing of locomotives which were about to be demonstrated to Riddles and Bond. At the same time the aerodynamics team at the wind tunnel were engaged in attempts to improve roof and ventilator design so as to obtain good smoke-lifting from the new standard steam running-sheds which were then being built. For his second series of experiments on this subject, Dennis Peacock was able to use the wind tunnel in reconstructed closed-return form and now re-housed more conveniently in the old Carriage Works stables. In this form, and after two more moves, it is still in use.

Having had one success in the accommodation field, Herbert began the search for a greater prize. He and Fancutt wanted a building or a site for a London Chemical Laboratory which would house the staff and activities from Ashford, Wimbledon, Stratford and Stonebridge Park. After bidding for a Marylebone site, they were offered the wooden wartime huts in the grounds of The Grove, Watford, a Victorian mansion that had been the wartime home of the LMS headquarters (including Herbert himself). The offer of the huts was rejected, but they are still in existence having been used by generations of railwaymen who attended the Work Study and Productivity and other courses at The Grove. Herbert and Fancutt's search continued.

In March 1953 financial matters were raised, in fact for the second time, when Herbert disclosed that the Research Department in 1952 had had an annual budget of £211,000 and had overspent by £11,750. Partly this was due to an unbudgeted contribution to ORE of £4,850. (This would not be the last time that the ORE contribution would be overlooked.) This was also the occasion when T Baldwin first put forward his proposal that a giant fatigue-testing machine should be acquired capable of testing to destruction a 65ft span double-track bridge. (Nor was this all – it was briefly suggested that the whole should be enclosed in a refrigeration chamber to allow low temperature testing.) The machine would of course have to be housed in the new Engineering Laboratory which all the faithful could see, dimly, on the horizon.

However in the more immediate future considerable dissatisfaction began to develop with the poor riding quality of passenger rolling-stock including, sadly, the newly built BR Mark 1 coaches as well as many older pre-war designs. Worse still, it appeared that nothing was being done about it, to the distress of the Research Advisory Council, the Passenger Manager and of course the passengers. Opinions varied as to whether the cause lay in the coach suspension design or the alleged deplorable state of the track. Within the Research Department J C Loach was regarded as the authority on permanent way; it was therefore decided in 1953 that he should be named Development Officer (Vehicle and Track Testing) and that he should have five additional technical posts. His freedom of action was incomplete as a committee on Interaction, Track and Vehicle, was to be formed but it seems likely that the Mechanical Engineering establishment declined to take part and Loach was left to his own devices.

The arrival of 1954 saw the Research Department in a well-established position. Staff levels had increased, although still inadequate; accommodation and facilities had improved, at least in Derby, and there was now considerable involvement in major aspects of BR's business. The Civil Engineers' requirements on testing and research on the permanent way became steadily more demanding, particularly when the Royal Scot train was derailed by a broken rail in a tunnel: this led to long series of special fatigue tests on rails and to an extended programme of measuring stresses at the bolt-holes in rails. Strain gauge tests on a bridge produced a rapid dividend when one such test resulted in the removal of a route restriction on West Country class locomotives at Plymouth. But it was the humble wagon which attracted most attention. Shunting tests at Ashford in connection with the development of the Oleo Pneumatic buffer revealed weak features in wagon structures and in their handling in mechanised marshalling yards such as Whitemoor and Toton to which further research effort had to be directed. But this was by no means the whole story. Attempts to run faster freight services produced a great increase in hot axleboxes; once again research action was required to examine the running behaviour of the oil-lubricated axleboxes and to search for better lubricants. Faster trains also required continuous brakes; the unsuitability of the vacuum brake was just making itself apparent and called for modern instrumentation to discover why. The last item in this tale of woe was the effect of the crude springing on the riding characteristics of the wagons and their frequent derailments. Clearly the problem of the wagon and of BR's attempts to run a competitive freight service was absorbing a lot of research resources from most of the Divisions and would continue to do so for a long time to come.

Frank Fancutt's star continued in the ascendant. In 1954 he pressed for equality with E Morgan, who was Deputy Director. Fancutt was successful again; he became Assistant Director in charge of the Chemical Services group now comprising Chemistry, Protective Coatings and Textiles; there was also a minor re-organisation or re-titling exercise for senior staff:

Dr G H Wyatt	became	Assistant (Special Duties)
C Walker	became	Assistant (Traffic and Dangerous Goods)
E D Henley	became	Assistant (Technical)
F G Dunkley	became	Assistant (Protective Coatings)
H Hayhurst	became	Assistant (Infestation)

E Morgan, who had obviously conceded a point in the hierarchical race, became the Assistant Director in charge of the "Technical" group comprising the Engineering, Metallurgy and Physics Divisions and had then to move to Derby to supervise his flock. Also, to align with the new responsibilities, Physics and Protective Coatings swapped locations, Physics returning to London Road. This move was disadvantageous to the (larger) Protective Coatings team, which lost space thereby and was separated from its paint samples, still on the roof at London Road. Only a little later, Textiles and Protective Coatings were joined in Cavendish House by a third unit, the newly-created Corrosion Laboratory in the charge of W J Hair, who joined the other Assistants with the title Assistant (Corrosion) in April 1955.

In his vehicle and track role, Charles Loach had become a keen disciple of the Frenchman Mauzin and the German Sperling who had introduced a method of describing the quality of ride of passenger vehicles in mathematical terms which produced a dimensionless parameter called the "Ride Index", so providing a basis of comparison between different rail vehicles. However, to get a specially selected and instrumented vehicle included in a service train to run at a preordained speed over an experimental piece of track was often a frustrating and time-consuming exercise. Loach decided that what was required was a special dedicated length of track ideally in the form of a continuous loop on which test runs of vehicles, perhaps over experimental lengths of track, could be made. Simultaneously the increasing pressure for action on vehicle ride (the new diesel railcars also rode abominably) led to an up-grading of Loach's position on 1 October 1955; he was put in charge of a new Vehicle and Track Division, thus confirming his release from the irksome tutelage of T Baldwin. Loach seized this opportunity to advance his test track proposal, for which he now suggested a site (at Wychnor, off the Derby-Birmingham main line) and a size – a continuous loop 8 miles long. His proposal was accepted by Herbert and formally submitted to higher authority.

It is now necessary to record that the higher authority just mentioned had by now changed considerably. An election in 1951 had brought a Conservative Government to power and in 1953 the Minister, empowered by the Transport Act of that year, ordered the abolition of the Railway Executive. The new Government disliked nationalisation and the statutory integration of transport. It also showed its dislike of the centralisation of the Railway Executive's management by splitting BR into six near autonomous railways (the Regions) each having its own Board and General Manager and each almost completely free to run their own railway. Nostalgia ruled: the old GWR with chocolate and cream coaches and green locomotives with copper bands on the chimneys was almost reborn. There was no separate BR headquarters management except that corporate BR was part of the BTC which still for the time being controlled all its original constituent parts, shorn of the term Executive in their titles (except in the case of London Transport). An interim organisation for the new-look BTC was hastily arranged in October 1953, pending the arrival of its new Chairman, General Sir Brian Robertson, in December. He then devised an extremely complex organisation which included a BTC General Staff which formed a communications hub (a military concept?), a BTC Central Services organisation and a BR Central Staff, as well as the Area Boards to supervise each BR Region. This organisation was introduced on 1 January 1955. In the BTC General Staff, John Ratter, who had been Chief Officer Civil Engineering in the interim organisation, became the Technical Adviser (to the Commission). Colin Inglis, the Chief Research Officer, was a member of the BTC Central Services. T M Herbert, as Director of Research, was a member of the BR Central Staff. He effectively had reporting lines to both Inglis and Ratter. The railway Chief Engineers stood organisationally alongside Herbert in the British Railways Central Staff.

Certain powers, known as the reserved subjects, still remained with the Commission. They included the setting of standards and codes of practice for the design, construction and maintenance of almost all BR's engineering equipment: the authority to co-ordinate research and development was another such power. For this reason an important committee was formed, named the Technical Development and Research committee, henceforward to be called the TD&R. Its membership consisted of four Commission Members (J L Train, F A Pope, Lord Rusholme and H P Barker) plus the Chief Research Officer (Inglis) and most of the Chief Officers of the BR Central Staff, including all the Chief Engineers but excluding T M Herbert. The Committee was normally chaired by J L (from 1957 Sir Landale) Train, who was a Civil Engineer and had been a Member of the Railway Executive; or by F A Pope, an operator and previously Chairman of the Ulster Transport Authority.

The existence and activities of the TD&R, commencing early in 1954, were of great advantage to the Research Department and to BR, since it provided a forum in which the long term technical direction of BR could be discussed by an informed group of people and appropriate decisions taken with a knowledge of their commercial and operating implications. It also gave a sympathetic hearing to Research Department requests. By 1955, when the TD&R had been in existence for two years, it had:

1) Agreed to the Research Department staff being increased by 40 new posts.
2) Taken positive action on the problem of riding by ordering 10 Commonwealth bogies for trial under Mark 1 coaches.
3) Agreed that BR and the LM Region should go ahead with electrification between Crewe and Manchester on the 25kV 50 cycles ac system.
4) Decided that three "Development Units" should be formed in order to obtain some progress in each of the fields of Signal Engineering, Locomotive Performance and Carriage and Wagon work. These Units were to be at London, Derby and Darlington respectively. Interestingly, the Civil Engineer declined to set up a Development Unit, preferring to use the services of the Research Department.
5) Discussed and reviewed the content and progress of the evolving Modernisation Plan.

The two committees formed earlier under the Stanier recommendations, namely the Research Advisory Council and the Research Co-ordination Committee, both continued in existence and the latter in particular continued to bring work to the Department: but their importance was progressively eclipsed by the TD&R Committee.

The direct control of British Railways by the British Transport Commission produced another desirable effect: it allowed Colin Inglis, the BTC's Chief of Research, to take a much closer interest in the affairs of the Research Department. He had joined a meeting of Research Superintendents as early as February 1954, and immediately pressed for a well-argued case for expansion, both of staff and facilities. From this point, expansion proposals took the form of a structured plan, with the successful outcome in terms of staff just noted. In terms of accommodation, by late 1955:

a) An additional building, 28 Euston Square, had been promised to accommodate Mr Fancutt and his headquarters staff and to allow the Operational Research Division to expand in the previously shared building at 20 Euston Square.
b) The eventual site had been chosen for the London Chemical Laboratory at Alexandra Palace (Muswell Hill). This was not ideal as access by public transport was poor. An alternative site at Ilford with better access had been considered, but was not selected.
c) The London Midland Region had been persuaded to allocate the Derby site for the new Engineering Research Laboratory, just across the London Road from the old building and at the time mainly covered by abandoned allotment gardens.
d) The concept of leasing a building in Derby (55 Ashbourne Road) as a temporary measure had been agreed.
e) The Commission had approved the concept of the Wychnor test site, although it still required parliamentary powers.

Item d) was the first to be implemented, in 1956, when the Vehicle & Track Division and some Engineering Division staff moved to Ashbourne Road. Items a), b), and c) followed respectively in 1956, 1959 and 1963. The Wychnor site was never implemented; perhaps the parliamentary powers proved too great a hurdle.

December 1955, then, saw the completion of the first five years of BR Research, a period in which the Department had become well established and involved in a number of research projects which were both scientifically satisfying and already showing their value to the railway. Also it should not be forgotten that research activity in the full sense was still only the minor part of the Department's work. In 1955, Herbert estimated that the expansion then in hand would raise the proportion of effort devoted to research proper only from one fifth to one third of the total. Thus the Chemical Laboratories continued to support the railway with their analyses of materials for production and operation, their classification of substances carried as freight, their advice on dangerous goods and their protection against claims and fraud. They also proposed and assisted in the introduction of ultra-violet sterilisers in restaurant cars to meet higher hygiene standards, and became increasingly involved in environmental matters such as air pollution. The Building Materials Laboratory at Wimbledon contributed its specialised advice. The Textiles Division (which had added a small King's Cross outstation in 1953) continued its acceptance tests of materials for uniforms, protective clothing, upholstery, etc., and answered queries, including from the Hotels Division on laundering. Protective Coatings in addition to their work on new materials and procedures supported production and dealt with applications problems. Fred Dunkley was also very active in organising Working Parties with both the Civil and Mechanical engineers to ensure that best practice was both understood and put to use. The new Corrosion Laboratory answered queries on boiler tubes, cast iron water pipes, aluminium alloy trusses and electrolytic attack on track components. Physics continued its control of signal lenses and answered calls on noise, heating problems and atmospheric pollution. For the Hotels Division, Physics examined dust filtration at the Queen's Hotel, Leeds, for which, interestingly, the LMS engineering section had recommended the appropriate acoustic treatment "with marked success" back in 1935. Even Engineering and Metallurgy had their share of routine service, such as Metallurgy's work on rail failures. So great was this on-going workload, that Herbert more than once expressed the view that BR Scientific Service would be a better title. However, the name Research stuck and, led by the Engineering Division, the proportion of original work continued to grow. Also by now Herbert had secured progress on his two great problems: the staff establishment had been increased by 50 posts since 1951 and accommodation had been improved, slightly in practice, but with much in prospect. Most importantly the Department had gained the confidence of the TD&R Committee, of Inglis and, it seems, of Ratter.

Chapter 12: BR Research 1956-1960

Following close upon the upheavals resulting from the 1953 Transport Act came the Modernisation Plan, the Government having been persuaded to make a sizeable injection of capital into the railway system – the first since 1939. A total amount of £1,240m was expected to be spent over the next 15 years. It was however inclusive of £600m that the railways would have had to spend in any case over that period on essential maintenance and renewals. A condition of the grant was that it should be used to fund an overall and co-ordinated plan, a requirement that had already been made difficult by the 1953 Act which had given so much power to the Regions and left so little with the centre. In the event the Plan, published in January 1955, envisaged allocation of the money to the following major items:

1) £210m for improvements in track and signalling to permit train speeds up to 100 mph. Most of this was to be spent on the installation of colour light signalling, power boxes, further track circuiting and major improvements to telecommunications.
2) £345m for replacement of steam locomotives by diesel or electric traction.
3) £285m for replacement of steam hauled passenger coaches by diesel or electric multiple units and modernisation of the remaining locomotive hauled stock. Money for new passenger stations and goods depots was also included under this heading.
4) £365m for remodelling of freight trains to operate at higher speeds, which was to include the fitting of continuous brakes to all freight vehicles, the construction of larger and improved wagons, and the installation of new large automated marshalling yards to replace many old yards.

To what extent was the Research Department consulted in the generation of the Modernisation Plan? Not at all, and only to a somewhat limited degree in the implementation of parts of it. Research had been closely involved for some time in the Civil Engineer's plans for improved track, as we have seen, and this work continued virtually unchanged in content although accelerated as much as resources would allow. There was of course no involvement in the Signal Engineer's plans, most of which were tied into the equipment supplier's technical developments. Nor was the Research Department invited to play any part in the choice, purchase or development of diesel traction; this was a matter which the Mechanical Engineer jealously guarded as entirely his own prerogative. It must also be admitted that because Research had been almost wholly excluded over the years from motive power matters the Department lacked the specialised knowledge and experience required to make any quick contribution. Neither was the Research Department invited to make any serious contribution to the new electrification projects, but here the situation was different particularly in respect of the proposed 25kV 50Hz ac electrification for which the UK suppliers had little direct experience. The Chief Electrical Engineer, S B Warder, had earlier recruited a small group of engineer/scientists (one of whom was Dr Ivan Andrews of Mobile Test Unit fame) to work in the New Works Office, and it was this group which, along with the English Electric Co., pioneered the 50 Hz electrification by means of an experimental installation between Lancaster and Heysham. This group would later grow into a full Electrical Research Section, as we shall see.

It should be recorded however that while the Engineering Division played little part in the dieselisation programme as it unfolded, the same was not true of the Chemists, who were frequently referred to for specialist advice; the case of diesel exhaust pollution has already been mentioned. Also at Derby S Bairstow had seen his controlled and regular interval locomotive firing system fade away with the promised demise of steam. What took its place was the control of diesel engine lubricating oil. As a steadily increasing number of different diesel engines arrived, each new engine came with the manufacturer's recommendation as to which (proprietary) oil should be used, for what purpose, and how frequently it should be changed. This presented BR with a major problem of storage at Depots of several different grades of oil for basically the same purposes. It was also expensive, since oil change by interval or mileage run often resulted in perfectly good oil being disposed of, or the retention in use of oil contaminated by coolant or by fuel oil or damaged by excessive heat. Bairstow began by working out fairly simple tests for oil quality that could be applied by staff at Motive Power Depots (other Area Chemists were moving in the same direction). He also arranged, by agreement with Regional Motive Power engineers, the frequency and methodology of laboratory testing and the actions that should follow when bad figures were obtained. In concert with the oil companies, generally applicable specifications for sump and other lubricating oils were prepared which all engines could use. Attention was then turned to other information available in the samples of lubricating oil. For example, the presence of chromium might indicate that leakage into the sump had occurred of cooling water using chromium compounds as corrosion inhibitors. Similarly it was anticipated that the amounts of iron, copper, aluminium or nickel particles detected might give information on the rate of wear of engine components, but to establish any correlation a sustained programme of research and collaboration with the Motive Power Department was needed. In addition, the detection of fine metallic particles required the use of modern spectroscopic analysis; a suitable instrument was quickly authorised by the TD&R Committee and purchased from Hilgers. Detailed development of the system of regular spectrographic analysis of diesel engine lubricating oils continued for several years and has been in established use now for many years. Its development was a major contribution to the economic operation of diesel traction and has been taken up by other operators of large numbers of engines such as the Royal Navy and the Royal Air Force.

While the part played by the Chemists in the progress of the Modernisation Plan was a success, the Engineering Division on the other hand seemed to become involved almost entirely with problem areas in which research was usually concerned with the humble four-wheeled wagon and was often unrewarding. That part of the Modernisation Plan concerned with the proposal to run freight trains fitted with continuous brakes at much higher speeds drew in both Engineering and Operational Research from the start. Unhappy experience had already been obtained on this matter when early experiments had encountered the great difficulty of releasing the brakes on long freight trains within reasonable time. Now the efforts to make continuously braked freight trains work became more urgent following the unfortunate decision by the BTC in 1956 to retain the vacuum brake, despite the strong recommendations of the BR Central Staff and the TD&R Committee that there should be a general change to the air brake. It is believed the BTC felt compelled to continue with the vacuum brake because of the strong opinions of Regional General Managers who envisaged chaos resulting from attempts to form up goods trains from wagons having incompatible brake systems. Whatever the truth of the matter, the Research Department found itself plunged into long and difficult experimental work attempting to make the essentially crude wagon operate satisfactorily in a modern high-speed environment. In fact the objective was impossible to attain with the vacuum brake, with unsatisfactory drawgear and buffers, with axleboxes prone to run hot as the speed approached 40 mph and with an unresponsive suspension often liable to derailment. A great deal of pneumatic, electronic and plain engineering ingenuity was expended on this part of the Modernisation Plan by both the Research Department and their Carriage and Wagon Engineering colleagues, generally to no avail. The secret of continuous brakes on freight trains lay in the use of the air brake and for that it was necessary to wait another eight years. Meanwhile the goods train continued to offer no competition to the road haulier in terms of journey time or reliability.

Another part of the Modernisation Plan, concerned with improvements to freight traffic, proposed the construction of a number of large strategically sited and automated marshalling yards. These would replace a considerable number of the small yards, many on the level, which still existed and which collectively imposed considerable delays on the passage of wagons to their destination. Visits to United States railways by groups of BR Traffic Officers had helped to reinforce the case for the automated yard in which each wagon was weighed as it passed over the hump and its velocity and acceleration measured just below the hump. From this data was calculated the amount of retardation needed to cause the wagon just to reach the right position in its destination siding, given the degree to which the siding was already occupied. Work done by the Ashford Laboratory staff had already demonstrated, at Whitemoor Yard (March, Eastern Region) and at others, that conventional retarder-equipped hump yards were unable to control the speed of wagons adequately to avoid damaging collisions. The group were then required to measure the effect on marshalling yards of having wagons fitted with hydraulic buffers, which had been successfully tested at Ashford, and to develop methods of measuring the “efficiency” of marshalling yards in the various regions. But the Ashford Laboratory was suffering from a chronic shortage of staff, which limited its capacity to about three project areas and made it unviable. Herbert and Baldwin therefore decided to close it in 1956 and transfer the staff to Derby – much to Baldwin’s relief as he had always found Ashford difficult to control. However the closure was a sad event for Byrne; Ashford had always been “his” laboratory. At Derby he was given no staff or managerial scope, but with great courage carved out for himself a new career as the BR expert on non-destructive testing. (He had done original and very valuable research into the propagation of ultrasonic waves in railway axles before leaving Ashford.)

The Marshalling Yard team now found their horizons widened to include studies of the newer yards which had varying degrees of mechanisation. Unfortunately the performance of all yards was highly variable so that a major research project developed to understand the causes of erratic wagon behaviour, to write tighter specifications and to begin to propose alternative methods of controlling wagon speeds. Once again, as in the case of the dieselisation programme and the braking of freight trains, the role of the Research Department was not to take part in the initial formulation of the policy, but rather to undertake a desperate rearguard action to make some of the policy work in practice.

Despite the accretions in workload arising from the unplanned and unexpected support to the Modernisation Plan, life continued to proceed normally within the Department on the customary projects. Within the Engineering Division, productivity in the regular work of testing and measuring stresses and accelerations was sharply increased by the acquisition of a small number of 12-channel galvanometer recorders. These could accept without any amplification the input signals from strain gauges or accelerometers, and gave clear pen recordings of adequate sensitivity and frequency response on special paper rolls. This may seem hardly noteworthy but it resulted in a considerable improvement over the situation that had existed in previous years, when only two channels at a time of cathode ray tube recording were available for dynamic events. For example the capacity for recording stresses in bridges was greatly enhanced in that not only could recordings be made from 20 or more strain gauges simultaneously, but they could be made during the passage of service trains or of special test trains over the bridge. Several existing bridges in main lines were tested in this way thus providing Bridge Engineers (and researchers) with an accurate statement of stress distribution in the structure due to different locomotives, different types of trains and different train speeds. The same equipment was also used for stress measurements on wagons during shunting, to record accelerations in coach bodies at speed or the output from load-measuring baseplates. A major increase in productivity had been obtained.

Investigations involving the problem of fatigue had by now exceeded the available testing capacity; but the demand was still increasing, particularly for the investigation of failures at bolt-holes in FB rails. Testing of different rail welding methods and of material and components from bridges, old and new, was also much in demand, so that there was an 18 month delay before any new work could be started. Two solutions to the problem were adopted: the first to purchase from Amsler’s further fatigue testing machinery (a pulsator and jacks) specifically for testing prestressed concrete sleepers and prestressed concrete cross-girders, the use of which in new bridge designs was then under consideration. The second solution was to send samples for testing to another fatigue laboratory having similar testing machines (and testing costs). Eventually the fatigue laboratory of the Swiss Federal Testing Institute in Zurich was chosen; at least one of their machines was kept busy on BR work for the next five years.

The TD&R Committee[3] continued to give support to the extension of science by its agreement to the purchase of significant items such as a track recording coach, to be supplied by Elliott’s and to be delivered to the Research Department for testing and calibration. It was based on a Wickham self-propelled four-wheeled coach and was required to be able to measure track gauge,

[3] In 1960, it would change its name to Technical Committee, to reflect its interest in the introduction of new technology, as well as its research and development.

curvature, “top” and cross-levels at speeds up to 40 mph. Ordered in 1956 it was delivered to Derby in 1957 but never succeeded in meeting its specification despite many returns to the makers. The authorisation to purchase the first research digital computer, an Elliott Type 402F, was a happier event although when delivered in 1958 it arrived shortly after the departure of the Department’s only mathematician for pastures new. Moreover, because of the shortage of accommodation the computer had to be housed in a wooden hut, an early version of a Portakabin. Nevertheless the arrival of the new computer marked a turning point in the history of the Physics Division. The establishment of (graduate) mathematicians was increased from one to three, and the previously minor role of mathematics in the Section’s work changed decisively. With new mathematicians recruited and existing staff trained, the computer was soon in valuable employment on stress calculations for concrete bridges, on predictions of the effect of different wagon draw gear on braking shocks, etc. Also by now acoustics, with studies of noise nuisance from locomotives and some industrial processes, was growing in importance and challenging the old pre-eminence of thermal studies.

But now what of the fortunes of the Vehicle and Track Division whose birth was recorded in the previous chapter? After a year spent in planning for the Wychnor test track and in obtaining instrumentation and a number of load-measuring baseplates, Loach was ready for expanded activity. In his new role, Loach had relinquished responsibility for work on the Permanent Way structure, which was now ably taken forward by his erstwhile assistant Donald Lindsay, reporting to Tom Baldwin in the Engineering Division. This work was now principally concerned with the development and testing of the optimum form of prestressed concrete sleeper and the concurrent testing of an apparently never-ending variety of rail fastening devices for securing the new 109lb/yd FB rail to the final form of concrete sleeper. Work was also continuing on stresses in the formation below the ballast. In the Vehicle and Track Division there was the study of the effect of new forms of motive power on the track: the Civil Engineer was already muttering about track damage on the newly electrified MSW route on which the new Co-Co and Bo-Bo locomotives provided the motive power. There were also fears that the newer and heavier traction motors in use on main line diesel locomotives (and some new EMUs) would be more damaging to the track than was steam traction. Here was an opportunity to use the load-measuring baseplates and tests were made both on the Manchester-Sheffield-Wath line and on the Southern Region with these devices. The results said in effect that, yes the MSW electric locomotives were worse than steam, but that little difference could be observed between the effect of the different types and sizes of traction motor. This conclusion was largely supported by the measurement of stresses in bolt-holes at rail joints, the subject of a long study at Duffield, then at Three Bridges on the Southern and later at Cheddington on the West Coast Main Line, although the tremendous scatter in the recorded stresses at different bolt-holes made any but very general conclusions on traction motors dubious.

Another subject which clearly concerned the Vehicle & Track Division was that of vehicle riding, which the Division had been remitted to improve. To this end a number of instrumented riding tests were made on a variety of coaches and some wagons, usually at the specific request of the Carriage & Wagon Department. Such tests were made on coaches with Commonwealth bogies, on others with the Metro-Schlieren bogies and on a set of vehicles the tyres of which had been turned to a coning angle of 1 in 50 in yet another attempt to solve the riding problem solely by changes in tyre profile. Most of these tests were initiated by the Joint Vehicle and Track Investigation Committee; in general they did not advance understanding of the problem, and merely described more precisely what was in most cases an inadequate performance.

The actual development of the Vehicle & Track Division was however influenced, if not determined, by a decision taken shortly after it came into being when it was decided that Loach, who had only junior or middle-ranking staff, was in need of a senior knowledgeable and experienced assistant. The problem was who? Most of the possible candidates from the CME organisation were clearly ineligible given the performance of the post-war designed coaches. The choice eventually fell (in March 1956) on a Mr J L Koffman, a Russian-trained engineer who was then working in a Ministry of Supply design office. He had railway experience in Eastern Europe and had developed a specialised interest in bogie design and vehicle suspensions well demonstrated by the many papers and articles he had written, usually on railway vehicle bogie and running gear design and often illustrating examples of German or East European practice. His approach was to analyse designs to determine the essential features common to all successful bogies including the calculation of frequencies and modes of vibration of key suspension components. It seemed certain that his specialised knowledge would be complementary to the permanent way expertise of Charles Loach and that the V & T Division would make significant progress. Unhappily it was not to be: the two men were totally incompatible. Loach was somewhat aloof, rather pedantic (particularly in matters of experimental technique) and proud of his status as expert on matters concerning vehicle and track on BR. Koffman was bright, witty and outgoing, but vain and very ambitious to be hailed as the authority on questions of vehicle behaviour that BR required. The situation was so serious that they failed to speak to each other for months. Obviously between them they failed to make any real progress on the problem for which the V & T Division had been set up; after three years Koffman was transferred to a senior position in the Central Staff design unit under E S Cox were he was made welcome. It was a sad position for Research, which had again failed to make any contribution to a most pressing problem for the passenger traffic business. The CME Department was probably happy that their opinion of the competence of the Research Department in matters other than track and materials had been vindicated, but it was certain that Inglis and the Research Advisory Council were most displeased. Koffman's post as Assistant to Loach was filled by John Littlewood, previously the senior man in Instrumentation, who, by demonstrating the possibilities of galvanometer recording with equipment borrowed from the Admiralty, had initiated the productivity advance referred to earlier.

Elsewhere in the Engineering Division there was an atmosphere of impending change. The prospect of new engineering laboratories had now become much greater once it was known that the LM Region had agreed that vacant land between the London Road and Etches Park Carriage and Wagon Depot, opposite the existing building, could be made available; TD&R support had already been given. As a result most groups were beginning to think what they would need if the money really became available. Tom Baldwin's plans for a huge fatigue testing machine now seemed to be marching forward and two German companies, MAN and Losenhausenwerke were actively developing designs to meet the outline specification. There was also the beginnings of a sectional structure developing within the Engineering Division in which Baldwin had up to then attempted to keep both staff and activities very much under his personal control. This was a wholly unofficial mini re-organisation and it had a number of untidy features. For example, the braking of freight trains was dealt with by Peacock and the investigation into wagon control in Marshalling Yards by D Turner; there was also another group under T Rhead studying the hot axlebox problem in wagons while one of his staff, Arthur Kettlety, was engaged in developing a new Automatic Train Control receiver based on a Hall-effect probe. (This was a rather extended investigation and used a whirling arm rig as well as track tests to assess ruggedness and reliability; however it achieved only limited use for triggering electrical switching on dual-voltage lines.) Stress distribution and strength of new tank wagons came under Wise and the Fatigue Group. With Loach having carved off a sizeable chunk of engineering work there was clearly a pressing need for some reorganisation and rationalisation within the "Engineering Division". This added to the pressure on Herbert, which had now become intense. Accommodation was still a problem, especially in London where the modifications to 28 Euston Square had fallen very much behind the plan. In addition the numbers of staff in post remained obstinately below the authorised complement. There was also the perpetual problem of action on the riding of coaches after the Loach/Koffman debacle and where the initiative seemed to be passing away from the Research Department. Maddison at the Rolling Stock Development Unit at Darlington was trying his hand at modifications to DMU bogies to improve the riding, Swindon had designed (with Koffman's collaboration?) and was building the first batch of the highly successful B4 carriage bogie, and the UIC/ORE had produced and standardised their twin link wagon suspension system. Unfortunately the latter was not directly applicable on BR since it was intended for wagons with 5 metre wheelbase and fitted with screw couplings to keep the buffer faces of adjacent wagons in contact. To overfill the cup of bitterness the proposed test track at Wychnor seems to have disappeared from view.

It was at this stage that Inglis decided to try to obtain a definitive decision on the proposal to build the new Engineering Laboratory, and to this end he suggested that the Chairman, Sir Brian Robertson, should visit Derby to see the value of the work in progress and the urgent need for the new building. The visit was duly arranged in November 1958 and by all accounts Sir Brian was impressed by the value of the work being done at Chemical Services under Bairstow, still in the Calvert Street laboratories. At the London Road Engineering Laboratories, E Morgan was in charge; his approach to management was of the "laid back" variety, leaving to the initiative of the Superintendents the projects they proposed to describe and the experiments to demonstrate. There was no attempt at co-ordination and the net result was near disaster since the impression was given that the entire laboratory – engineers, mathematicians, physicists and even metallurgists – were deeply involved in concrete sleeper matters. Sir Brian was not amused, and among other remarks is reputed to have cast doubts on the future of Morgan's career. But fortunately the Chairman was an ex Royal Engineer and could see beyond poor administration to the importance of the work in hand and its potentiality. He endorsed the new laboratory project and the Commission's approval "in principle" was soon achieved; the process of obtaining financial authorisation from the Ministry of Transport, however, would prove to require two years more.

An organisational change, which had been under discussion for some time, was effected in 1958. The Operational Research Division, its role always very distinct, was transferred out of the Research Department to become the responsibility of the Traffic Adviser, one of Mr Ratter's colleagues on the BTC General Staff. In its early years, the Division had addressed a variety of topics: policy for bonus payments, arrangements for passengers' luggage, the design of ticket machines, responsibility for issuing station stores, and – a classic problem – the effect of price on passenger receipts. There was also a long investigation into the "consumption" (i.e. the partial disappearance) of locomotive coal. Latterly however, the pressing needs of the business had concentrated effort more and more onto freight operation: punctuality (or the lack of it), problems caused by the severe daily traffic fluctuations, the benefit of better advanced information, the effect in marshalling yards of having to couple and uncouple the new continuously braked trains, and the prospect of timetabling freight trains by computer. Even apart from freight, the Division's studies had a strong operational bias: for example assessing the cost of stopping and restarting multiple units, the value of improvements to train reporting systems, and the prospects for a nationwide fixed-interval passenger service. Thus the case for an organisational change was made, and the unit commenced a long and productive independent existence, which still continues.

Also in 1958 the Library staff – the Librarian was now Miss I E (Betty) Harvey who had succeeded Mary Hastings in 1956 – were strengthened by the recruitment of two full-time translators, Miss Erika Theumer and Frank Case. This allowed the department to cope, in-house, with the growing demand for translations. The production of the Monthly Review of Technical Literature, the circulation of journals and the loaning of technical material continued as before. A principal reason for the growth in demand for translations was the extensive activity of members of staff on the committees of ORE. This involved particularly the more senior members of staff, many of whom were highly regarded in ORE circles: F Fancutt for example was internationally accepted as an authority on paint. T M Herbert was himself a member of the Management Committee of ORE.

In the next year, 1959, the most important occurrence within the Department was the completion and occupation of the new London Area Chemical Laboratory at Muswell Hill. This was designed to provide facilities for Chemical Research, which did not exist on any reasonable scale elsewhere, and also to house the work previously done at Wimbledon, Stratford and Stonebridge Park. A Research Chemist was sought; meanwhile Dr Gordon Wyatt took over the London Area Chemist responsibilities. The Corrosion Laboratory also moved to Muswell Hill. In Derby, S Bairstow was promoted to Assistant Director (Derby) and moved to Cavendish House; Eric Henley took over at Calvert Street. The long awaited improvement to accommodation in London and the clear signs of promise for the new Engineering Laboratory in Derby made it possible to plan further improvements for Chemical Laboratories, the first of which was certain to be the transfer of the Derby Area Chemist from the miserable accommodation in Calvert Street to the 1935 LMS building in London Road when vacated by the Engineers. The eventual availability of this more spacious building also revived plans for centralisation at Derby of much of the vast quantity of routine analysis by using instrumental rather than wet-chemistry methods, and offered the prospect of performing new analyses, not previously practicable.

Apart from the excitement in the London Area, life in the remainder of the empire remained more or less normal. In the Annual Report for 1959 Herbert made special reference to great advances in the actual use of glass reinforced laminates for DMU and EMU cab canopies, experimental containers and for carriage doors. Most of this work was inspired by the Chemists, particularly Bairstow and Henley, who laid down the methods and kept a keen eye on Quality Control. Successful trials with automated spray painting of coaches were noted, as was significant progress in the organisation of diesel locomotive lubricating oil testing by spectrographic analysis. The Textile Division's "flagship" project on a new type of wagon sheet was making progress, if slowly. The Corrosion Laboratory had produced recommendations for inhibitors to use in diesel engine cooling systems. Stress measurements had been made on a number of bridges carrying traffic and compared with computer-based stress analysis by matrix methods of the same structures, presaging greater reliance on computation in the future. In addition to their matrix structural analysis, the mathematicians were busy with train timing calculations and train running simulations. Reference was made to developments with "direct admission" valves for wagon braking and the limited progress made on this subject was compared with the steady progress on optimisation of prestressed concrete sleeper design and with combating the problem of fatigue failures at bolt-holes at rail ends. Progress was being made on most subjects, but the problems studied were still the same!

In the Engineering Division pressure was still rising for a major re-organisation particularly at senior staff level; comparisons could be drawn with two other research outfits which had quietly sprung up. The first of these was the Western Region Chief Civil Engineer's Research group at Paddington, which was based on the Soil Mechanics Laboratory instituted in the early days of BR. Numerically this group was as large as the Engineering Division at Derby although it had few qualified men. It is described in more detail in the next Chapter but its principal claim to fame was that it was doing original and fundamental work on the stability of long welded track, a subject not then tackled at Derby.

The second group was the Electrical Engineering Research Section set up by S B Warder, the Chief Electrical Engineer (BR Central Staff), aided and abetted by Colin Inglis who was concerned that the official Research Department ignored completely questions of railway electrical engineering. The formation of Warder's Research group had by now been formally approved by the Commission and a well reputed scientist, Dr. F T Barwell, an authority on friction and surface physics, had been appointed to lead it. He had earlier collaborated with the railways on wheel-rail adhesion (limiting friction) under the auspices of the Research Co-ordinating Committee. It is interesting that "Electrical Research" did not concern itself much with the problems of the standard dc traction motor, but with more fundamental work such as adhesion, mathematical analysis of catenaries, the dynamics of current collection from overhead lines and track-to-train communication and control. In support of the adhesion work, a special rig was constructed in a redundant sub-station building at Willesden, and brought into use in 1957. It comprised a 100ft length of track over which a specially adapted bogie could be driven, weighted down and with motors separately controlled. A common arrangement for the adhesion studies was to drive the two axles in opposition. It was clear that both of these extra-Research Departments were doing work the scientific quality of which was the equal of the best work being done at Derby.

The next year, 1960, saw at last the beginnings of the great breakaway from the LMS and Hartley practices which had controlled BR Research for so long. It began with the break-up of Baldwin's Engineering Division into a series of separate Sections each under a Superintendent at the same level as Baldwin. These Sections were in fact similar in function to those that had begun to form unofficially two years before; this time leaders were recognised and paid appropriately. They were:

Vehicles	Superintendent	T Baldwin
Instrumentation	Superintendent	P H Mansfield

Structures	Superintendent	J C Lucas
Mechanical Testing (later Strength of Materials)	Superintendent	S Wise
Drawing Office & Workshop	Superintendent	W S Holdbrook

At the same time the Vehicle and Track Division was absorbed, J C Loach taking responsibility for an enlarged Permanent Way Section. These new Sections, together with Metallurgy and Physics, reported to E Morgan as Assistant Director, but not for long – Morgan was suddenly given a post at headquarters, 222 Marylebone Road, where, still with the title of Assistant Director, he found himself in charge of the Libraries at Derby and London, the list of projects in hand and relations with ORE. The latter involved seeking BR representatives to Committees, dealing with ORE reports and organising the payments to and from ORE. It has to be remarked that after Morgan's posting to London, Baldwin took charge at Derby again, in an acting capacity, which suggests that the old French proverb "Plus ça change, plus c'est la même chose" was applicable. But the new Superintendents guarded their independence carefully.

1960 was effectively the last year of the T M Herbert era. He retired on 30 April 1961 at the age of 60. His last annual report (for December 1960) mentioned that it was the 29th such report he had produced as Director of Research or its equivalent: "far too long for one man", he wrote. He had a difficult period in office faced with almost continual opposition, not to say hostility, from the Technical Officers for most of that period. He had a detached manner and a faint air of intellectual superiority when a more outgoing personality might have helped him. He had no difficulty in maintaining authority over his subordinates, but he did little to encourage or to drive them into taking new approaches to problems, being apparently content with getting solutions to the relatively minor problems which fell his way. With his retirement the Harold Hartley era had finally ended. Sadly he died only two and a half years later, in 1963, and so did not live to see the completion of his long-cherished project, the new Engineering Laboratory in Derby.

Chapter 13: BR Research from 1961 – A New Era Dawns

The early 1960s brought changes of far-reaching consequence, both to British Railways and to its Research Department.

For the Railways as a whole, the late 1950s had seen financial deficits mounting inexorably, caused amongst other things by a persistent fall in freight traffic and by a large pay award – welcome enough to Research staff – following the Guillebaud report. The British Transport Commission seemed unable to stem the tide, and was in any case coming under increasing pressure over its failure to target the Modernisation Plan effectively onto the commercial needs. This caused the (Conservative) government to take several actions, including the redefinition of objectives for all the Nationalised Industries (to break even again within 5 years) and the commissioning of the Stedeford Advisory Group to recommend a future organisational strategy for the BTC. One member of this 6-man group was Dr Richard Beeching, then Technical Director of ICI. Beeching soon formed strong views on the proper direction of the Railways, and, once the Group's recommendations reached the Minister, Ernest Marples, these views prevailed. Thereafter matters moved quickly. In June 1961 Dr Beeching was seconded from ICI and appointed to replace Sir Brian Robertson as Chairman of the British Transport Commission. His remit was to prepare for the new regime soon to be enshrined in the 1962 Transport Act. This Act created a British Railways Board free of responsibility for other transport modes (although still retaining hotels and holdings of operational land). Dr Beeching was duly appointed its first Chairman and the Board commenced operation on 1 January 1963. The Railways then came for a time under strong and well-focused management, with the emphasis on organisational streamlining, on obtaining "new blood" and on the now famous "reshaping". The latter was set out in Beeching's policy document "The Reshaping of British Railways" published in March 1963.

In the Research Department, we have seen that T M Herbert retired from the post of Director of Research in the early months of 1961. In the previous year he had reorganised the Department into two Divisions only: Chemical Services and Engineering. New posts were created to lead these Divisions, titled respectively Assistant Director of Research (Chemical Services) and Assistant Director of Research (Engineering). Frank Fancutt was immediately appointed to the former post. E Morgan had been moved to Headquarters, as we have seen, and for a short period Tom Baldwin headed the Engineering Division in an acting capacity. At the same time, Herbert had obtained authorisation for four additional senior posts, two reporting to each of the Assistant Directors of Research, the new posts being also confusingly titled Assistant Director. With Frank Fancutt himself due to retire in mid 1961, there was clearly now great scope for fresh leadership, obtained either by external appointment or promotion.

Three new appointments were already announced before Herbert's departure. In the Chemical Services Division the Assistant Director post in Derby was filled on promotion by S Bairstow, whose work on locomotive firing, on oil analysis and on plastics has already been described. The Assistant Director post at Muswell Hill was then filled by an external appointee, Dr L C F Blackman, who joined from Imperial College having previously had experience of coal combustion research with the National Coal Board Research Department. Most importantly, to head the Engineering Division, the appointment was announced of D L Bartlett. His title of Assistant Director of Research (Engineering) would later be changed to Director. Don Bartlett was then about 35 years of age, had been commissioned in the Royal Marines and held a degree in Civil Engineering. He was a new appointment to the Research Department, although not to the Railways, having previously led the conspicuously successful work of the Western Region Civil Engineer's Soil Mechanics Laboratory at Paddington. This justifies a short digression.

The Western Region Laboratory at Paddington had its origin in the decision of the late 1940s to retain soil mechanics investigations as a responsibility of the Regional Civil Engineers. Quite soon the Western Region became the acknowledged leader in this field – somewhat to the chagrin of A H Toms of the Southern – and was allocated the “research” element of the business, such as the development of new testing methods. From this, and no doubt encouraged by the increased independence of the Regions under the 1953 Act, the Paddington Laboratory developed quite a wide range of civil engineering research activities. These included fundamental soil mechanics studies, some important aspects of track design, cement grouting of structures and numerous other investigations on behalf of the Western Region’s District Engineers. Accordingly the staff and facilities expanded, the Section moving in 1953 from the two basements of 137/139 Westbourne Terrace, Paddington, to better accommodation on two floors of the GWR block at 66 Porchester Road nearby. The workshop and instrumentation facilities then became quite extensive, and their output demonstrated a positive genius for improvisation under the leadership of ex-Naval Chief Artificer Toby Burton, aided by a plentiful supply of war-surplus equipment and machine tools “liberated” from railway workshops then in the process of rationalisation. A major subject in this expanded activity was the resistance to buckling of continuously welded rail. This was studied experimentally on running lines (with synchro-repeating displacement transducers) and by means of a special test length set up in the disused Mousehole tunnel just across the main line from the laboratory. There a 120ft length of track, anchored to concrete blocks at its ends, could be heated to induce buckling and its behaviour measured. This work was complemented by theoretical analysis by a Mr Tuora, one of several Polish expatriates in the Section, and by experimental work on rail fastenings in the Laboratory by Mervin Dart. All this was in the charge of D L Bartlett, who had succeeded to the post of manager of the whole laboratory on the departure of its former head, Mr Protopapadakis, in 1958. Thus by the end of 1960, Bartlett could show 3 years’ leadership of a dynamic and successful research group, as well as a definitive paper on the stability of long welded track. An infusion of the vigour and enterprise shown at Paddington to the rather staid Engineering Division in Derby augured well for the future of the latter. In the meantime John Waters, who we shall meet again, was left in charge at Paddington.

Subsequent to Bartlett’s arrival in Derby, his two Assistant Director posts were filled on promotion by Tom Baldwin (taking responsibility for Vehicles, Instrumentation, Physics and the Drawing Office and Workshop) and Sam Wise (Permanent Way, Metallurgy, Strength of Materials, and Structures).

Meanwhile the search for a successor to Herbert was under way, Colin Inglis taking direct control of the Department when necessary. In line with Beeching’s “new blood” philosophy an external appointment was evidently desirable, and the choice ultimately fell upon Dr Sydney Jones, then Technical Director of R B Pullin Ltd and previously Director of Applications Research of the Central Electricity Generating Board. Prior to that he had worked at the Royal Radar Establishment at Great Malvern and on airborne gunnery control at the Royal Aircraft Establishment. Sydney Jones was Welsh, eloquent and persuasive, and far more ready than Herbert to take new initiatives in research and to press forward with developments which the research showed to be promising. His influence would soon be felt when he took up his duties in the spring of 1962.

Surveying his new responsibilities, Dr Jones soon became aware of several anomalies. No doubt with the help of Colin Inglis, he set about correcting these. Firstly he took note of the two groups doing excellent research, but outside his Department: the Western Region Civil Engineer’s team at Paddington; and the Electrical Research Section under Dr “Freddie” Barwell operating from laboratories in Marylebone, Rugby and Willesden. By February 1963, both of these research groups had been transferred to the “official” Research Department. In the case of the Paddington Section this required the separation of the research element from the routine soil mechanics work in line with an agreement already reached between Bartlett and the then Chief Civil Engineer A N Butland. The research element under John Waters reported straight through to Don Bartlett but remained for the time being at Paddington. It thus represented a strengthening of the Engineering Division, albeit outbased. The Electrical Research Section on the other hand formed a complete new Division, Dr Barwell as Director of Electrical Research taking a title equivalent to Bartlett’s Director of Engineering Research. The Electrical Research Division retained its original locations with headquarters in Blandford House, Marylebone. Its organisational transfer corrected at a stroke the lack of electrical expertise in the Research Department.

Secondly Dr Jones found within his Department certain activities which were very doubtfully classed as research, although they had certainly met Herbert's interest in providing a scientific service. This applied particularly to the work of the Textiles Section, and arrangements were made to transfer the main activity to the Chief Mechanical Engineer. Three staff were retained for research. The Head of Section, C G Winson, moved to assist the Chief Supplies and Contracts Officer. Some of the more routine activities of the Protective Coatings Section were also transferred to the Chief Mechanical Engineer.

Finally, in his first year of office Dr Jones took decisive action on the matter of vehicle riding which had hung fire for so long. He created within the Engineering Division a new section – Theoretical Dynamics – and recruited as its first head A H Wickens. Alan Wickens came in October 1962 bringing extensive experience of aeroelastic work acquired in the aerospace industry, most recently with A V Roe and Company at Woodford, Cheshire. The classic unsolved problem was the unstable "hunting" behaviour of railway vehicles. Clues as to its cause had existed in the academic literature for many years. Being familiar with the properties of non-conservative systems, Alan Wickens was at last able to appreciate these earlier suggestions, and quickly gained an excellent understanding of a phenomenon which had troubled railway engineers for a century and more.

Two earlier appointments had also brought important new talent to the Engineering Division. The vacancy at Superintendent of the Strength of Materials Section, caused by the promotion of S Wise, was filled by Dr B J Nield, a metallurgist of wide interests, who came from the Safety in Mines Research Laboratory in Sheffield. Before this, P J Coates had arrived to lead the Mathematics Group within the Physics Section, like Wickens bringing up-to-date expertise from the aerospace industry. He would soon be promoted Superintendent of the new Mathematics Section which was split away from the Physics Section in 1963. He would also act for a time as Superintendent of the Physics Section while a successor was sought for Eames (see below).

Before Dr Jones' arrival Bartlett had taken initiatives within the Engineering Division to improve the management of its work. Until that time:

1) There had been no central record of the workload within the various Sections. All sections were therefore required to identify and describe their projects in hand, and a serial number was allocated to each project, and a register kept.
2) There had been no control over the initiation of projects. Some were formally requested by Chief Officers, some arose out of Committee discussions and some from casual telephone conversations. It was decided that in future all projects should be subject to formal approval. This was to involve the preparation and acceptance of a Project Initiation Order describing the origin and justification of the work, its content and expected cost.
3) There had been no knowledge of the relative cost of individual projects. A costing and budgeting system was therefore devised and implemented.

A further weakness lay in the planning area. Up to that time, no systematic thought had been given to the relative value to BR of competing projects; nor was the potential considered of work that could be undertaken but had not been requested. It was therefore decided to set up a small planning group to consider these matters. First I G T Duncan was allocated to lead it, being detached from his work on stresses in bolt-holes. As the work grew, T A Eames was asked to supervise it in addition to his role as Superintendent of the Physics Section.

When these developments were brought to Dr Jones' attention, he approved of the steps taken in respect of project control and extended them forthwith to the Chemical Services Division. He also welcomed the attention given to planning, but decided that this activity should be undertaken at headquarters level, not in one of his Divisions. This led in 1963 to the appointment of Dr K H Spring, who had experience of similar work at CEGB, as Director of Research Planning at Marylebone (Blandford House). The small planning group at Derby was disbanded, seconded members returning to their parent sections. Eames however was retained and moved to Marylebone to assist Dr Spring.

Another significant administrative change was completed in early 1963. This was the division into two of Fancutt's old responsibility, the Chemical Services Division. (Fancutt had not been replaced.) There had long been a healthy demand for the service element of the Division's work; but Dr Jones also felt that a significant contribution could be made to the railways' operation by new research initiatives in chemistry. However less radical attempts at building up the research side of chemistry had persistently failed to take root. Accordingly Dr Jones formed two new Divisions: Chemical Research based at Muswell Hill under Dr Blackman (but with Protective Coatings as an outstation in Derby); and Regional Scientific Services under S Bairstow. The latter had his headquarters and one laboratory in Derby and eight out-based Area Laboratories, one of them housed with Chemical Research at Muswell Hill. The other seven were at Ashford, Crewe, Darlington, Doncaster, Glasgow, Horwich and Swindon. The Infestation Section in Manchester and the small Dangerous Goods team at Muswell Hill also formed part of Regional Scientific Services. This completed the reorganisation of the Department into four Divisions. All Divisional Heads now carried the title Director, the two Chemists being the last to achieve this distinction.

In the Engineering Division work had continued steadily on planning for the new laboratories. These had been approved in principle as early as February 1959 – allowing the preparation of architect's plans and estimates – but the final authorisation (which required Ministry approval) was only obtained in April 1961. When Dr Beeching took over as Chairman of BTC in June 1961, he requested a review by the other Dr (F E) Jones, famous for his wartime work on radar and then Deputy Director of the Royal Aircraft Establishment. Beeching also visited Derby himself to assess the work in hand and the architect's proposals. The review was evidently favourable, as no great delay ensued; the main contract for the building was let in September 1961.

When Dr Sydney Jones arrived on the scene therefore, work was well in hand. The contract for the large-scale fatigue testing plant had been let to MAN at Nuremberg in West Germany, the scheme having been worked up in discussions between E S Burdon of the Strength of Materials Section and W Fuhrmann of MAN. (Burdon later had to take firm action with the Architect's Consulting Engineers to ensure that the suspended floor of the main test plant should go ahead as he intended.) The new building incorporated other new facilities such as an anechoic chamber and a reverberation chamber for acoustical work. Also the workshop and drawing office space was greatly enlarged. Otherwise the new building re-housed existing facilities, including the digital computer from its temporary accommodation. Meeting the requirement to allow for expansion, the buildings comprised a five-storey office block, a hollow square of single-storey laboratories and, via a link corridor, a tall single-storey block containing the fatigue plant, the workshop, and a vehicle preparation bay soon partly taken over as a dynamics laboratory. The digital computer, installed in the single-storey wing closest to London Road, was soon joined in the next room by an analogue computer in support of the dynamics studies.

By November 1963 the new building was ready for occupation. The move was planned in great detail by the administration staff and executed over a weekend so that on the Monday (11 November) the technical staff had only to find their new offices and unpack their crates and hampers. The following few months were far from relaxed, however, as the date for the official opening had already been set at 14 May 1964 and the services of HRH Prince Philip Duke of Edinburgh booked for the occasion together with a number of the Great and the Good of the scientific, engineering and railway worlds. So numerous were the guests, in fact, that they were divided into 3 groups in order of importance: the "party" who sat on the dais with the Duke, the Lord Lieutenant and Dr Beeching during the speeches in the courtyard, and later lunched with the Duke at the Midland Hotel; the "guests" who sat in the centre of the courtyard in a specially erected marquee (which had blown down in a gale the previous day) to hear Dr Beeching and Prince Philip speak of the need for more scientific research, and lunched in the Common Room; and the "spectators" who had a more fleeting view of the proceedings. After the introductions (which included John Ratter the Technical Board Member, Inglis, Jones, Bartlett, Wise, the Architect F F C Curtis and Professor A Tustin, the last chairman of the Research Advisory Council) and the speeches, Dr Beeching invited Prince Philip to perform the opening ceremony by unveiling the large plaque in the foyer which still records the event. He then invited Mr Bartlett to lead the top party's tour of the laboratories. This time the demonstrations had been carefully planned and fully rehearsed. (The surviving Administration Instructions give the timings in hours, minutes and seconds; and the party was accompanied by a radio operator – J M M "Robin" Stirling – to report progress to "control"). The guests followed the same route after lunch.

The items shown included:

- Continuous control of marshalling yards (L B Banks and M A Tanvir) and the computer simulation of same (P J Coates and T H Weeks).
- Stress analysis of an ac locomotive bogie frame (Dr B J Nield and J Davies).
- The large-scale fatigue plant (E S Burdon and F Hunt).
- Fatigue strength of cross girder connections (J C Lucas and P E West).
- Distribution of dynamic loads in track (J C Loach, H K Johnson and D Heath).
- Fifth-scale roller rig and model four-wheeled vehicle (A H Wickens, B L King and R Barron).

Although the day essentially belonged to the Engineering Division, the newly acquired Electrical Research Division also showed two items in the sidings area:

- The linear motor (Dr F T Barwell)
- Surface wave radar (H H Ogilvy)

It is pleasant to record that one of the members of staff, apart from exhibitors, introduced to the Duke was Basil R Byrne, then Assistant Superintendent of the Physics Section, for "50 years service" – a record of commitment to railway science not often equalled even at that date.

When the festivities were over and the Captains and the Kings had departed, work did not immediately return to normal. On the following Thursday and Friday, 21/22 May, Open Days were held for visitors from academia and industry and for families with a much wider range of exhibits, including four from Regional Scientific Services and one (the effect of vibration on the corrosion of metals in aqueous solutions) from the Chemical Research Division. Then the staff did indeed return to work, but not to the old ways. A new ethos was now firmly established with a much stronger emphasis on fundamental studies and an energetic search for more creative lines of research.

For the Regional Scientific Services Division the remit was indeed little changed. However availability of new accommodation now offered scope for improved methods of working, in particular a change from "wet" chemistry carried out in many small laboratories to instrumental chemistry performed centrally. In Derby, as Herbert had intended, the old Engineering Laboratories were refurbished to accommodate the chemists from Calvert Street and Cavendish House, and a single-storey extension was added at the south end to form a Central Analytical Laboratory. This was duly equipped with direct reading emission and X-ray fluorescence spectrometers for the analysis of metals, an infrared spectrometer and an argon gas chromatograph for organic analysis, a flame spectrophotometer and a cathode ray polarograph. These new facilities were formally opened by Mr John Ratter on 20 November 1964.

The Chemical Research Division in 1964 was still in its early days and was busy developing its new lines of research. These would be added to its established workload in Building Materials and Protective Coatings. Time was also needed to acquire familiarity with their new equipment, including electron microscope and X-ray diffraction set. Early ventures included a number of topics in battery technology, plus a feasibility study into the use of fuel cells as prime movers, energy storage systems and signalling power supplies. There was also a group of studies in surface chemistry, such as the wettability of surfaces, corrosion of surfaces, anti-static treatments, metal plating etc. Also an investigation was commenced into the chemical treatment of frost heave. By mid year, Dr Blackman had left the service, and for a time Dr Spring acted as Director in addition to his duties as Director of Research Planning. But by November their new Director, Dr K G A Pankhurst, was in place, having previously been Head of the Pioneer Research Unit of the Reed Paper Group, and the generation of new lines of work continued with great enthusiasm.

In the Engineering Division, an example of the more fundamental approach has already been seen in Wickens' attack on vehicle dynamics. In 1963 he expanded his team; two external recruits were A E W Hobbs and the present Editor. Wickens' stability theory was rapidly developing into a practical prediction method. It was soon put to use on the pressing problem of the four-wheeled wagon, some examples of which were all too prone to derailment. Extensive experiments were organised by the Field Trials Section on a test length at Mickleover. These, and the model-scale tests already mentioned, helped to confirm the theory. By late 1964, stability predictions could be made with some confidence, and, most importantly, a way could be shown to design vehicles to run stably. A start had also been made on the prediction of response to track irregularity, both laterally and vertically.

Another example of the modern approach was the development of digital computing, where in spite of a primitive machine, simulations (of train performance and marshalling yard movements, for example) and structural analysis moved ahead strongly. Also fatigue studies developed in more fundamental directions, aided by the new test equipment. By now the excessive reliance on the Civil Engineer as client in this area was beginning to be corrected as weaknesses due to fatigue manifested themselves in Modernisation Plan vehicles. Two component types in particular required attention: axles and welded structures. In the case of axles, the new ultrasonic techniques revealed large numbers of axles of all types running in service with fatigue cracks in the wheelseats. Warlow-Davies in 1942 had first recommended raised wheelseats to improve fatigue life: extensive model-scale tests were now undertaken to extend his work from trailer axles to the new DMU and diesel locomotive axles. The objective was to determine the influence of axle geometry, rather than metallurgical factors that had been emphasised in the past. The upshot of the work was a design code issued in 1967 which virtually eliminated axle fatigue cracking, in wheelseats and elsewhere. The influence of geometry was also a feature of the work on welded structures. This was aided by the use of the then available BS 153, a bridge code, to relate shape to allowable stress for a range of different weld geometries. Many successful modifications were applied to welded components to effect dramatic increases in service life. Early examples included welded locomotive bogie frames and the crankcase fabrications of both the Mirrlees and the larger Sulzer diesel engines. These successes encouraged the CM&EE department to ask Research to provide a training course for its senior design engineers who in turn trained their junior staff in weld design – a far cry from the old attitude where fatigue failures were always metallurgical in origin.

In August 1964 Dr R W Sparrow was appointed Assistant Director in the Engineering Division. He replaced Tom Baldwin who decided to retire that year, having underpinned and guided the progress of Derby engineering research from its very earliest years. "Bob" Sparrow came from lecturing in Civil Engineering at the University of Nottingham; but in fact this marked his return to the railways. He had earlier worked for a year at the Paddington Soil Mechanics Laboratory and then for two years in the Permanent Way Section in Derby. Indeed his work was known to the railways even before that, when his cell for soil pressure measurement, developed as part of his doctoral work, was compared favourably with the offerings of Toms and Loach. On his return to the railways, Bob Sparrow would soon action the earlier agreement to bring Soil Mechanics research to Derby, creating a new Section with John Waters as its head and merging staff at Derby, notably Don Heath, and staff from Paddington. Very fundamental work was undertaken on the behaviour of both subsoils and ballast, with important consequences for the future. Work continued on the track superstructure. A feature of all this work on track was the growing collaboration with ORE; this provided useful additional funding and also gave the fundamental work added credibility when viewed by the staff of the Chief Civil Engineer's Department. Meanwhile work on civil engineering structures addressed both the residual strength of old bridges and the design of new ones. For the former, the fatigue strength of wrought iron was a major subject of study; the latter included the cross-girder connection study shown at the Opening. A little later, attention was given to two major "heritage" structures to clear them for higher loads: the Royal Albert bridge at Saltash and the Britannia bridge at Menai. Calculations on the latter had just been completed when the bridge was destroyed by fire in 1970.

With the now distinct disciplines of the two Assistant Directors, Wise and Sparrow, the work of the Engineering Division was organised under Mechanical and Civil Engineering headings.

Mathematics, now separated from Physics, was classed with Permanent Way, Structures and Soil Mechanics to form Civil Engineering; Physics and Special Problems (successor to the old Vehicles Section and under Luen Banks) joined Strength of Materials, Metallurgy and Dynamics to form Mechanical Engineering. By now the Field Trials Section already mentioned had been created under John Littlewood to relieve the specialist Sections of the extensive and detailed administration involved in setting up out-based experiments. It and the Instrumentation Section reported through to the Director.

At the end of 1964 D L Bartlett announced that for domestic reasons he wished to return to living in London and that in the new year he would take up the position of Technical Assistant to John Ratter, the Technical Member of the Board. Since the Chief of Research (now Dr Jones following C C Inglis' retirement in August) reported to the Technical Member, this meant that Don Bartlett would still have an interest in the affairs of the Research Department. Even so, there were many that regretted his departure as he had made a considerable impact in re-vitalising and improving the management of the Engineering Division and was both well respected and well liked by the staff. He would be succeeded in 1965 by S F (Stan) Smith, then Chief Research Engineer with the Aero Engine Division of Rolls Royce Ltd.

Already by 1964, the Electrical Research Division had established a number of forward-looking projects, very advanced for their date. The linear induction motor (a collaboration with Professor Laithwaite) and the surface-wave radar train-detection and communication system have already been mentioned. They illustrate the two strands of heavy and light current electrical work that were to characterise the Division's activity for many years. The former included, even in 1964, the study of solid-state 3-phase inverters for control of induction-type traction motors, the simulation of pantograph and overhead line dynamics by computer (analogue computer at this stage) and studies of polymeric high voltage insulators. The work on adhesion, although ultimately unsuccessful, was also carried on at a fundamental level. The light current area related to signalling and train control, and included novel means of train detection, track-to-train communication methods, the automation of some signalling processes (generation of control tables and automatic route setting) and even the automatic operation of trains. Studies of track-side warning devices were also already underway. The Division had its own instrumentation and mathematics capabilities. It placed extramural work with Universities (the overhead line simulation was done at Cambridge) and retained Professor A Tustin of Imperial College as adviser on heavy current topics.

Thus the close of 1964 found the Research Department in a strong position. Its organisational structures and procedures had been improved. New staff had been brought in to fill important posts. The physical facilities, in terms of both buildings and equipment, had been much improved. Indeed the situation in Derby, with the new Engineering Research Laboratory in operation and the chemists at last moved out of Calvert Street, was transformed. More needed to be done, particularly for the Electrical Research Division and some of the remoter chemical laboratories, but the staff had good reason to look to the future with confidence.

Postscript

ALASTAIR GILCHRIST

As it turned out, Sam Wise's completed text covered exactly one hundred years, from 1864 to 1964. In this he succeeded where an earlier attempt at a history, made to mark the centenary itself (and the opening of the new Engineering Research Laboratory), had failed. His narrative reveals the continuity of the chemical effort throughout the period, from its origins within the private railway companies to its carrying forward by Regional Scientific Services from 1963. With the Grouping, metallurgy gains in importance and independence; but, most importantly, engineering emerges as a research discipline, tentatively on the Southern Railway and definitively on the LMS. Indeed, in retrospect, the importance of the LMS's decision in 1932 to create a multi-disciplinary research department is clear. Its only weakness requiring later correction (in 1963) was its limited electrical engineering expertise. Otherwise the LMS concept was taken forward in an expanded form by the British Transport Commission after 1948, and transferred seamlessly to the British Railways Board in 1963. Over this long period consistent and valuable technical support was given to the parent businesses.

Where the narrative breaks off, the repositioning of the Research Department commenced by Colin Inglis and continued by Sydney Jones was well advanced. Its objectives had been to raise the quality of both staff and facilities, to develop a "more cohesive" research programme containing more long-term and less ad-hoc work, and to gain for the department some initiative in the selection and progressing of research topics. The incorporation of the Electrical Research Division, the creation of the Chemical Research Division and the Theoretical Dynamics Section and the construction of the new Engineering Research Laboratories all formed a part of this policy. Total staff numbers had also been increased, to some 540, by 1964. As already mentioned, Stan Smith came in to replace Don Bartlett in 1965; he injected great enthusiasm for advanced projects. In the same year, Dr L L (Liviu) Alston replaced Dr "Freddie" Barwell as Director of the Electrical Research Division. Dr Alston was an electrical engineer and also proved very energetic in promoting new projects, particularly in the areas of signalling and control. Then in November 1965, the status of the department was further strengthened by Dr Jones' appointment as Board Member responsible for research. A consequence was S F Smith's promotion to Director of Research (while temporarily retaining responsibility for the Engineering Division); Dr Spring became Headquarters Research Manager. Finally, in 1966, an Advanced Projects Group was added to the four existing Divisions, Alan Wickens being appointed to lead it; Bob Sparrow was appointed Director of Engineering Research in March 1967. This gave the Department the five-division structure that would soon be called upon to support a major expansion.

During this period, Regional Scientific Services' structure was simplified and its accommodation modernised. Three laboratories were closed. The activity at Horwich was withdrawn to Crewe, that at Darlington to Doncaster and the Ashford work was transferred to Muswell Hill. The enlarged Crewe laboratory was then relocated to the twelfth floor of the new Rail House there, while new custom-designed buildings were provided for the Glasgow and Doncaster laboratories. Both were opened in 1969. This left only the Swindon laboratory in its original nineteenth century accommodation.

Immediately following his appointment to the Board, Dr Jones obtained approval to approach Government sources for funding for long-term research which could be considered a part of the national effort on ground transportation. Three years of negotiation followed, which yielded, by late 1968, an agreement to expand the research effort with funding contributed equally by the Ministry of Transport and the British Railways Board. The "Joint Programme" was thus cleared to commence in January 1969; it would run for sixteen years, until March 1985. From the start its two major projects were the Advanced Passenger Train and the Train Control Project; however it also provided for a general expansion of effort in other disciplines, including civil engineering, structures and strength of materials, tribology, electron microscopy, electro-chemistry, aspects of electronic computing and so on. This allowed progress to be made on a very broad front.

The authorisation of the Joint Programme signalled the start of a vigorous recruiting drive. The increase in staff numbers and activity in turn required new buildings. A Track Research laboratory with attached office building was occupied in October 1969, an Advanced Projects Laboratory and a 13-mile test track were added in 1970, and a complete new office block (Brunel House) with attached laboratories was opened in 1971. Prior to this, the Board had commissioned the extension of the Railway Technical Centre site, completed in 1967. This had allowed the Chemical Research and the Electrical Research Divisions to be brought to Derby, the former joining the Engineering Division in its building (now Kelvin House) and the latter moving into its own custom-designed building (Lathkill House). Finally pressure on Kelvin House was relieved by the building of a new library block in its courtyard (1972).

During the currency of the Joint Programme, there were several changes of internal organisation. In 1970, Dr Spring was appointed Head of Research. Stan Smith chose to move to London Transport, and Liviu Alston left to join the World Bank. In 1971 Alan Wickens effectively succeeded Stan Smith, but now with the title Director of Laboratories. Wickens then introduced a new organisation with two Deputy Directors: Dr Sparrow (Engineering) and Dr Pankhurst (Applied Science). The responsibility of the former now included Electrical Engineering, and of the latter Scientific Services. Each Deputy Director was supported by a group of Project Managers, while a Group Manager Vehicles (Mike Newman) reported through to the Director. At the same time, the department changed its name to Research and Development Division. In 1973, the design responsibility for the Advanced Passenger Train (and a group of staff) moved to the Chief Mechanical and Electrical Engineer, and the Vehicles Group busied itself with development support to the APT and other vehicle innovations.

In June 1975 Dr Jones retired as full time Board Member. He was succeeded first by Mr R L E Lawrence, and then by Mr I M Campbell who was appointed Board Member with responsibility for Engineering and Research in January 1977. With his railway background as Regional Civil Engineer and General Manager, Ian Campbell was helpful in improving relations between the R & D Division and the railway at large; he was also active in the creation of industrial partnerships. Both elements were to prove important for the success of projects that came to fruition in the 1980s.

In 1978 Dr Spring moved to the Strategic Planning Unit and Dr Wickens was appointed Director of Research (although his department continued to carry the Research and Development title); his appointment brought the head of department's post to Derby for the first time. Dr Sparrow became Deputy Director of Research with responsibility for all technical activities. (Dr Pankhurst had retired, and his successor, Eric Henley, would retire in 1979.) Ralph Wall became Assistant Director with administrative responsibility. The technical sections ("Units") were now grouped into five "Branches" by discipline, as Civil Engineering, Mechanical Engineering, Electrical Engineering, Scientific Services and Technical Support. With refinements, this Branch and Unit structure would outlive the Joint Programme. However at senior level, in 1984, Dr Wickens' responsibility became that of Director of Engineering Development and Research; Dr Sparrow was appointed Director (Research) and a small development coordinating activity was introduced under Peter Law as Assistant Director (Development).

Staff numbers reached their peak of 957 in 1975. From 1980, successive Board initiatives for cost reduction caused staff numbers to reduce to about 800 by 1985.

Over its life, the Joint Programme funded much valuable research. The Advanced Passenger Train project, although ultimately unsuccessful, progressed many points of technique used in later developments. Vehicle stability theory was well established at the outset. Prediction of the behaviour of vehicles in curves was improved progressively, reaching its definitive form by 1978; numerous experiments were conducted with the APT test vehicles to verify the theory and to establish safe limits for high-speed curving. These included very thorough measurements of the lateral strength of ballasted track. In support of the prototype design, research areas included structural technique (notably using welded aluminium extrusions), tilt actuation and control, and suspension enhancements (including active control). Braking systems of hydrokinetic and a variety of friction types were examined, together with their associated wheel slide protection. Aerodynamic studies related to the APT – streamlining, tunnel entry, safety in gales – and also to conventional stock and the then current Channel Tunnel proposals. New ventures, following the transfer of the APT design responsibility, included low cost vehicle proposals, of which the successful railbus was an example, and the magnetically-levitated vehicles which entered service at Birmingham Airport in 1984. Both projects involved industrial collaboration. A number of advanced bogie designs were also offered, including a low track force bogie for freight and a steering bogie for rapid transit vehicles. Finally, improved methods were developed for predicting the dynamic behaviour of pantograph and overhead line, and a high-speed pantograph was produced in association with Brecknell Willis.

The Train Control Project, from its earliest years, included many advanced concepts, much ahead of their time for implementation. The signal-repeating advanced warning system SRAWS retained cab indications of signals passed and included an automatic train stop. An on-train speed supervision system was devised for control of APT. Automatic control of trains was developed, initially with “wiggly wire” track conductors as the transmission medium providing cab signalling and extendable to any desired level of automation of the driving function. Experiments were at Mickleover, Wilmslow and Eggborough power station. Computer logic was applied to train operating decisions with a pilot Junction Optimisation Technique installed in Glasgow. By the mid 1970s this work was well advanced and attention was directed towards items which could be interfaced with existing signalling systems and operational practices to achieve early implementation. In this way the Automatic Route Setting system was installed at Three Bridges in 1983 and Solid State Interlocking was commissioned at Leamington Spa in 1985. The latter involved an important “tripartite” agreement with the two signalling suppliers GEC and Westinghouse. Radio Electronic Token Block, in contrast, represented a novel operational procedure suited to lightly used lines; it was first introduced in Scotland in 1985. At the very end of the Joint Programme, “computer-based control-centre research” appears; this would lead to the Integrated Electronic Control Centre combining ARS, SSI and video-screen displays, first introduced into service at Liverpool Street in March 1989 and widely deployed thereafter. In parallel with this Joint Programme work, a very extensive survey of radio field-strengths was undertaken for the Signal and Telecommunications Engineer’s National Radio Plan, using the test coach Iris.

From the general Expansion (“XP”) Programme, a number of physical “products” emerged: paved concrete (“slab”) track, developed in conjunction with Robert McGregor and Sons, was an early example and the pneumatic ballast injection machine (“stoneblower”) a late one. A rail (axial) force transducer was designed and deployed to monitor the safety of continuously welded track – the first of a number of safety monitoring devices. High-manganese crossings, which could be welded into plain rail, were developed in conjunction with British Steel and Taylor Brothers. Vehicle mounted instrumentation was devised for the monitoring of track: for the high-speed track-recording car, two generations of rail-flaw detection car and a structure gauging train. However, the major legacy of the programme was the fundamental understanding gained in a wide range of subjects. A thorough understanding of the geometrical deterioration of ballasted track under traffic led to proposals for improved maintenance practice. Rail wear and rail surface damage mechanisms were identified. Prediction methods were established for track dynamics, track buckling and for noise and vibration caused by rail traffic. The causes and statistics of low wheel/rail adhesion were established. Fatigue prediction methods were refined, structural analysis and computer aided design methods improved, and the use of adhesives and composites investigated. Advances in electric traction equipment were also pursued. Finally, in parallel with the detailed technical work, economic studies were made of the potential application of various technical advances; from 1974 this was the special province of the Transport Technology Assessment Group.

In the last years of the Joint Programme, as the period of retrenchment started, some topics were deemed to be no longer appropriate to a railway research department. Thus the work on the sodium sulphur battery, long under development, was privatised (by management buyout in 1982) and the plastics development activity transferred, on a reduced scale, to British Rail Engineering Limited (in 1984).

Throughout the period of the Joint Programme, a sizeable proportion of the Department's work continued to be undertaken on behalf of the rail businesses (mainly the Chief Engineers). This was always the main source of income for Scientific Services and was a significant element in the work of the other Branches. There was also a small element of work commissioned by outside parties. Together these provided typically 45% of the department's income. With the termination of the Ministry contribution, these became the main source of funding; as the Sectors and then the Rail Businesses were formed, they in turn became the main sponsors of the work. However, to maintain an element of long-term work in support of its corporate aims, the Board continued to fund first an Exploratory and then a Strategic Research programme. New theories continued to be developed: for example for masonry bridges and the mechanism of rail corrugation. Also established theories were recast in consolidated computational form, as vehicle dynamics in VAMPIRE. The Strategic programme contained an important safety-related element: crashworthiness of vehicles, reliability of train detection, security of braking in adverse conditions, avoidance of signals passed at danger, etc. Aspects of environmental protection were also included: for example energy conservation and noise reduction. In the business-sponsored work, the development of computer-based planning tools became an important element. These related to track maintenance activity, depot operations, the planning of track layout and signalling, and the introduction of condition-based maintenance practices. Hardware developments included the stoneblower, already mentioned, ballast cleaners, automatic track alignment, improved switch and crossing work, the advanced suburban bogie and others.

During the period 1985-1989, rationalisations within the Branch and Unit structure enabled staff numbers to be further reduced to about 700. Then in 1989, in line with a Consultants' report, Dr G W Buckley was appointed as a new Director of Research (the Development responsibility was dropped) with a remit to establish the Department on a more commercial footing. Dr Wickens and Dr Sparrow retired. Dr Buckley introduced a new senior structure of four Directors (Technical, Commercial, Finance and Personnel), while retaining the Branch and Unit structure in a modified form. In 1992, when the Board created a new business, Central Services, Dr Buckley moved up to lead it. The Research Department became one part of it, in the process gaining several elements from the Chief Engineers' departments and changing its name to Engineering Research and Development. Dr M G Pollard succeeded Dr Buckley as Director of Research.

From 1993, strenuous steps were taken to reduce the size of the department and to prepare it for sale in line with Government policy. The business was renamed British Rail Research, Dr Pollard's title becoming Managing Director. Then in 1994 the Scientific Services Branch was separated off (but still within Central Services) and renamed "Scientifics". Its Muswell Hill laboratory had already been closed, after two years under Network SouthEast management. In 1996 the Crewe laboratory was also closed, leaving some 115 staff distributed between the Derby, Glasgow, Doncaster and Swindon laboratories. Within the remaining British Rail Research, the Branch structure was finally replaced, first by seven Capability Groups (in 1994) and then by five Business Groups (in 1996). At this point staff numbers had been reduced to about 260 and all could now be accommodated in Kelvin House (including its 1972 library block, now converted into offices). In 1996 also, Paul Wise succeeded Dr Pollard as Managing Director. Finally in December of that year, Scientifics Limited was purchased by Atesta Group Limited and British Rail Research Limited by AEA Technology plc.

The continuity of effort already noted, in Chemistry from 1864 and in Engineering from 1933, thus continued unbroken to the point where the research activity was returned to private ownership in 1996. The two-way division Chemistry/Engineering, first introduced in 1960 but long retained within a single department, now emerged as two separate businesses. In this form, therefore, the knowledge base developed over this long period continued to be available to the railway industry. With the latter now much fragmented, the availability of these sources of consultancy and testing and development expertise could be expected to be particularly valuable.

Appendix: Source Documents

ALASTAIR GILCHRIST

Sam Wise did not leave a record of his sources. The following notes list relevant documents that I am aware of and have used to check the text.

CHAPTER 1: IN THE BEGINNING – APPLIED CHEMISTRY

A group of documents relevant to this early period are held by Scientifics Ltd in their Derby Archive, catalogued by Hudson and Gilchrist. They include: a group of letters responding to Thomas Henry Turner in 1930 on the history of the LNER laboratories (DA 601); an account of the LNER Chief Chemists Department written in November 1941 by their Chief Clerk, Mr Lilly (DA 360); a group of letters commissioned by R Emrys Jones in 1962 on the history of all the British Railways laboratories (DA 351); Emrys Jones's own "Brief History of the British Railways Research Department, Area Chemical Laboratory, Crewe" dated May 1961 (DA 69); and an unpublished history of "Research on Railways" commissioned with Bryan Morgan and abandoned at galley proof stage early in 1965 (DA 565). There also exists a printed booklet "Area Laboratory Crewe Centenary 1864-1964" (BR Record Centre). The Morgan text is not completely reliable and is only used when other sources are lacking.

These are all secondary sources. The period is now being re-examined by John Hudson of Anglia Polytechnic University Cambridge for a doctorate at the Open University, and his search is unearthing useful primary sources. The table on pages 5 to 6 has been revised with his help, using data extracted from these primary sources.

The Minutes of the Railway Chemists' Committee are preserved in Public Record Office RAIL 1080 808 onwards; the committee was initially formed in 1893 to support the Committee of Goods Managers on Explosives and Other Dangerous Goods of the Railway Clearing House.

A contemporary description of the work of the Swindon laboratory is given by G E Brown in the *Railway Magazine* of 1898, page 58.

CHAPTER 2: THE GROWTH OF RESEARCH BETWEEN THE WARS

Herbert's work on firebox stays is reported in O F Hudson, T M Herbert, F E Ball and E H Bucknall "The Properties of Locomotive Firebox Stays and Plates", J. Inst. of Metals, Vol. 42, 1929, pp 221-319. Herbert had earlier reported limited data in his own name in "Locomotive Firebox Conditions: Gas Compositions and Temperatures close to Copper Plates", Proc. Inst. Mech. Eng., Vol. 115, 1928, pp 985-1006.

A good description of the work of the Crewe laboratory, before its incorporation into the new Research Department, appears as "Chemical Laboratory, Crewe" in the LMS Magazine, 1925, pp 342-344.

Noticed in *The Railway Gazette* are: the appointment of Sir Harold Hartley (issue of 7 February 1930); the appointment of Sir Henry Fowler as Assistant to Sir Harold Hartley and E J H Lemon as Chief Mechanical Engineer, effective from 1 January 1931 (issue of 30 October 1930); the appointment of T M Herbert and the five Section Heads (Dr P Lewis-Dale, F C Johansen, E Millington, W Pritchard and F Fancutt) in the new LMS Scientific Research Department (issue of 2 December 1932), and an editorial on the creation of the new Department (issue of 30 December 1932). On 21 February 1936, a biography of Mr M G Bennett includes "in 1935 the Physics Section of the Research Department was formed and Mr Bennett was appointed to take charge of this [in addition to other duties]".

A biography of Sir Harold Hartley appears in his *Times* obituary, 11 September 1972.

Copies of the Souvenir Brochure issued for the opening of the new laboratory on 10 December 1935 survive, one as PRO RAIL 429 31, and one as NRM G8/2.

T H Turner himself gives an account of his work on boiler water treatment in the Gresley Observer No. 58, Autumn/Winter 1976. He gives a very full description of his work for the Civil Engineer in "Permanent Way Metallurgy", J. Permanent Way Inst., Vol. 57, 1939, pp 179-213.

For the LNER laboratory organisation, Lilly (DA 360) is now a contemporary source.

CHAPTER 3: LOCOMOTIVE TESTING

The "Locomotive Testing Plant at Swindon" is described in *The Engineer*, Vol. 100, 1905, pp 617, 621-3 and supplement.

H N Gresley's two presidential addresses to the Institution of Locomotive Engineers are in their Journal Vol. 17, 1927, p 558 and Vol. 24, 1934, p 617.

H I Andrews described "The Mobile Locomotive Testing Plant of the LMS Railway" in Proc. Inst. Mech. Eng., Vol. 158, 1948, pp 450-476. A much earlier description by him is in a typescript dated 1939 in the BR Records Centre. The MTUs are also described in *The Railway Gazette* of 5 September 1947 and briefly in *Carry On* (the LMS/LMR in-house magazine) for July 1948, PRO ZPER 15 1.

The opening of the Rugby Testing Station was well covered in the technical press, see for example *The Engineer*, Vol. 186, 1948, pp 487-491 and 524-526, *Engineering*, Vol. 166, 1948, pp 462-465 and 487-489 and *The Railway Gazette*, Vol. 89, pp 490-494. See also *Carry On* for December 1948, PRO ZPER 15 1.

D R Carling's two papers on locomotive testing are "Locomotive Testing on British Railways", J. Inst. Locomotive Engineers, Vol. 40, 1950, p 496 and "Locomotive Testing Stations", Transactions of the Newcomen Society, Vol. 45, 1972-73.

A description of S O Ell's work at Swindon appears under "Locomotive Testing at Swindon", *Engineering*, 23 May 1952. His scientific conclusions are described in his "Developments in Locomotive Testing", J. Inst. Loco. Eng., Vol. 43, 1953, p 561.

CHAPTER 4: THE SOUTHERN RAILWAY CONTRIBUTION

Sam Wise would have written this chapter from personal knowledge: he worked at the Southern's Ashford laboratory from 1944 to 1953 and knew all the principal characters. Therefore I have not had occasion to search for source material.

F Hargreaves published his fundamental studies on soft-metal properties in a series of papers in the J. Inst. Metals between 1927 and 1930, for example "Effect of Work and Annealing on the Lead-Tin Eutectic", J. Inst. Metals, Vol. 38, 1827, pp 315-339; see also Vol. 37 (1927) pp 103-110, Vol. 39 (1928) pp 301-327, Vol. 40 (1928) pp 41-54, Vol. 41 (1929) pp 257-288 and Vol. 44 (1930) pp 149-174.

CHAPTER 5: CONTROL OF THE LMS RESEARCH WORK

Sir Josiah Stamp announced the creation of the Advisory Committee for Scientific Research to the seventh Annual General Meeting of the LMS (see *The Railway Gazette* of 7 March 1930). The Minutes of the Committee from its first meeting (2 July 1930) to its thirty-first (11 July 1939) are held as PRO RAIL 418 169-170; also an isolated forty-third meeting on 26 October 1948 as PRO AN 97 186. A short set of submitted papers from January 1937 to July 1939 form PRO RAIL 418 171-172. However a complete set of Minutes up to the final (forty-fifth) meeting on 12 April 1949 and a virtually complete set of submitted papers exist at the BR Record Centre. The latter include, as well as technical papers, a series of half-yearly departmental progress reports.

R D Davies gave a distillation of the work at Cambridge University on the dynamic behaviour of railway vehicles in his "Some Experiments on the Lateral Oscillation of Railway Vehicles", J. Inst. Civil Engineers, Vol. 11, 1939, pp 224-261 and 278-288. The title is somewhat misleading, as theory is also included.

Johansen published his results, some four years after completing his experiments, in "The Air Resistance of Passenger Trains", Proc. Inst. Mech. Eng., Vol. 134, 1936, pp 91-208.

Sir Josiah Stamp pays tribute to Mr William Rintoul (died 25 August 1936) and Sir Herbert Jackson (died 10 December 1936) at the 14th Annual General Meeting of the LMS (*Railway Gazette*

5 March 1937). The decision of the LMS Directors to create a medal to commemorate Sir Herbert Jackson's contribution was reported to the Advisory Committee for Scientific Research on 13 April 1937.

The Minutes of the LMS Board's Scientific Research Committee are held as PRO RAIL 418 70, covering its complete life from 26 January 1939 to 17 December 1947 (32 meetings).

CHAPTER 6: THE LMS RESEARCH DEPARTMENT AT WORK – MECHANICAL ENGINEERING

Sam Wise no doubt received assistance from Tom Baldwin in preparing this chapter. Documentation includes an article on the Research Department's work under the heading "Science and Progress" in *The Times* LMS Centenary Number, 20 September 1938. Sir Josiah Stamp comments on the Department's achievements at most of the LMS Annual General Meetings throughout the 1930s (not 1935), as does he, or his successor, in 1941, 1942, 1943, and 1945. A late description of the department was published in booklet form in the latter half of 1946; titled "The Scientific Research Department of the LMS", a copy is held as NRM G8/3. Also, since the LMS department effectively continued under LM Regional management until the end of 1950, the Half-yearly Report to the Research Advisory Council of June 1950 (BR Record Centre) is of value.

Porter's work on curving was serialised and then published in booklet form by The Railway Gazette (London, 1935). A severely abridged version is Proc. Inst. Mech. Eng., Vol. 126, 1934, pp 457-461. An obituary appears in Proc. Inst. Mech. Eng., Vol. 127, 1934, p 432.

A high proportion of the Engineering Research Section's internal technical reports survive and are held as PRO RAIL 792 1-1057. A letter code identifies the author.

Johansen's recommendations on streamline forms are given in his internal reports J 16/36 "Air resistance of a 3-car articulated unit", 8 October 1936 (RAIL 792 272) and J 12/37 "Streamlining experiments on a 4-6-2 locomotive no. 6220 Coronation", 24 September 1937 (RAIL 792 288). Johansen later reissued the latter report with a slightly fuller text and with illustrations as J 6/39 "Development of streamlined form of 4-6-2 class 7P locomotive Coronation by means of wind tunnel experiments", 18 May 1939 (RAIL 792 308).

The key report in which Warlow-Davies recommends the raised wheel-seat is WD 24 "Data for designing carriage axles with high fatigue strength at wheel seat", 3 February 1942 (RAIL 792 1037).

Newberry published the vehicle riding work which made use of his cine camera technique as "A Study of the Riding Qualities of Carriage Tyres having Various Profiles", Proc. Inst. Mech. Eng., Vol. 153, 1945, pp 25-40. His work on engine balancing is internally reported in N 104 "Engine slipping tests", 4 September 1939 (PRO RAIL 792 785).

The conclusions of the work on locomotive tyres in the 1930s and on locomotive frames in the 1940s are both nicely summarised by Baldwin in his paper "Significance of the Fatigue of Metals to Railways", Inst. Mech. Eng. International Conference on Fatigue of Metals, 10-14 September 1956. On the former he cites himself (J. Inst. Loco. Eng., Vol. 28, 1938, pp 649-721) and C W Newberry (Proc. Inst. Mech. Eng., Vol. 142, 1939, pp 289-303) and on the latter E S Cox with F C Johansen (J. Inst. Loco. Eng., Vol. 38, 1948, pp 81-196).

CHAPTER 7: THE LMS RESEARCH DEPARTMENT AT WORK – CIVIL ENGINEERING

The survival of the Engineering Research Section's internal reports (PRO RAIL 792 1-1057) is relevant to this chapter also.

Loach gives a detailed description of the scratch extensometer in his report L 90 "Observations made on reinforced concrete sleepers: brief description of methods and apparatus used", January 1943 (RAIL 792 588).

The work on the new rail sections, including the photoelastic studies, was published by Loach in his "Contributions of Research in Modern Rail Design", J. Permanent Way Institution, Vol. 70/3, 1952, pp 153-168.

For the work on welded rail, see J C Loach "Experiments with a Long Welded Lenth of Bull-Head Rail Railway Track", Inst. Civil Engineers, Railway Paper No. 3, October 1942; for the work on reinforced concrete sleepers, F C Johansen "Experiments on Reinforced Concrete Sleepers", Inst.

Civil Engineers, Railway Paper No. 13, 16 May 1944. The work by F G Thomas of the Building Research Station on the sleeper support forces is in the following paper, no. 14.

I have not traced a full description of the Orpington tests, but a passing reference in J C Loach "Research in Retrospect", J. Permanent Way Inst., 1967, dates them to 1950.

The work on the fatigue strength of rail using the resonant-rail testing machine is mentioned by both Baldwin in his 1956 paper (above) and by Loach in his 1952 paper. The machine itself is described by L B Banks in "Machine for Testing Rails in Bending Fatigue", *Engineering*, Vol. 169, 1950, p 585.

CHAPTER 8: THE LMS RESEARCH DEPARTMENT AT WORK – METALLURGY AND PHYSICS

It is very likely that Sam Wise received help from John Dearden in preparing the section on metallurgy. Although the chapter heading is Wise's own, no text describing physics has been found; as mentioned in the Preface, I have provided some.

Dr H O'Neill's appointment as Research Metallurgist was reported to the Advisory Committee on Scientific Research at their meeting on 10 July 1934 (PRO RAIL 418 169). Mr E Millington's retirement on 31 December 1935 is recorded in PRO RAIL 426 9.

Two later typescripts describing the work of the Metallurgy Section contain information relating to this period (see below under Chapter 10).

Only a small number of the Metallurgical Section's internal reports are known to have survived (about 40, including the LM Region period up to 31 December 1950). They are catalogued and held at the BR Record Centre. In addition some 50 occasional (unnumbered) reports survive from LMS days, but only four or five are of metallurgical interest. Finally a proportion of the papers submitted to the Advisory Committee on Scientific Research (see under Chapter 5 above) relate to metallurgy.

O'Neill's work on coupling rod steels was published by him as "Alloy and Fine Grained Steels for Locomotive Coupling Rods", J. Iron and Steel Inst., Vol. 135, 1937, pp 187-221.

The paper on the welding of alloy steels is: J Dearden and H O'Neill "A Guide to the Selection and Welding of Low Alloy Structural Steels", Trans. Inst. Welding, Vol. 3, October 1940, pp 203-214.

O'Neill gave a substantial description of the work on rails in his "Metallurgical Studies of Rails", Inst. Civil Engineers, Railway Paper No. 15, 1944-45.

The research on the separation of metals was published by J N Bradley and H O'Neill in "Railway Bearing Metals: their Control and Recovery", J. Inst. Metals, Vol. 68, 1942, pp 259-279.

The paragraphs on the Physics Section's work incorporate reminiscences of Leslie Thyer (joined 1936), Douglas Wright (transferred to Physics 1940) and Roy Bickerstaffe (joined 1943). Written information is contained in the general sources noted under chapters 5 and 6, including the papers of the Advisory Committee for Scientific Research, the *Times* centenary supplement, the 1946 LMS booklet and the June 1950 half-yearly report. *Carry On* for April 1949 included an article on the work of the Physics Section (PRO ZPER 15 1).

Only one numbered report from the LMS Physics Section is known to survive: 8/44 "The proper use of averages in comparing experimental results", 5 September 1944 (BR Record Centre). Two of the LMS occasional reports are of physics interest.

Memorandum 155 to the Advisory Committee for Scientific Research (March 1937) is an excellent paper by Eames on refrigerated transport. His external publications include "The Nature and Purpose of Physics as Applied to Some Railway Problems", J. Scient. Instruments, Vol. 20, November 1943, pp 169-175 and "Refrigerated Transport by Rail: Some Limitations and Possibilities", Proc. Inst. Refrig., Vol. 41, 1944-45, pp 83-109. In the former, in his section on Refrigeration and the Transport of Food, he cites four earlier references by W H Glossop (1932), Sir Harold Hartley (1935) and F C Johansen (1934 and 1941).

Thyer reported his work on boiler water level gauges in a report series which just postdates our period (PRO AN 145, see chapter 10 below): in Ph 37 (January 1951) and F 49 (June 1952). He later rounded the subject up in a series of three reports, F 75-77 (all December 1958).

CHAPTER 9: THE LMS RESEARCH DEPARTMENT AT WORK – CHEMISTRY, PAINT AND TEXTILES

Sam Wise no doubt received assistance from Stanley Bairstow when drafting this chapter; I myself had help from Fred Dunkley when editing the section on paint. All the department-wide sources, mentioned above, include substantial references to these subjects: the papers of the Advisory Committee for Scientific Research, the Souvenir Brochure of 1935, the *Times* centenary supplement of 1938, citations to the LMS Annual General Meetings, the 1946 LMS booklet and the June 1950 half-yearly report. *Carry On* for August 1948 contains an article on the Chemistry Section's work and the issue for September 1948, an article on Paints.

The outline history of the Stonebridge Park laboratory is given by Emrys Jones in his "Brief History" (DA 69); the appointment of Dr Macfarlane as Senior Research Chemist is noted in *The Railway Gazette* of 25 March 1938.

A typescript note by Hayhurst on the history of the Infestation Service is included in the group of papers DA 351. The first of his many publications is: H Hayhurst "Insect Infestation of Stored Products", Ann. Appl. Biology, Vol. 24, 1937, pp 797-807.

The work on combustion and boiler efficiency was published by P Lewis-Dale "Some Measurements by Gas Analysis of the Efficiency of the Locomotive Furnace", J. Inst. Fuel, Vol. 10, 1936, pp 68-78 followed by V Binns and S Bairstow "Combustion Control by Means of Electrical Meters", same reference pp 79-86. Lewis Dale also described the work for the LMS Magazine, 1935, pp 273-275. The work on producer gas appeared in H Webster, S Bairstow and W A Macfarlane "The Relation between Calorific Value and the Road Performance of Producer Gas Vehicles", J. Inst. Fuel, Vol. 15, 1942, pp 93-100.

The appointment of Mr Henderson as Chief Chemist, Euston, is reported in *The Railway Gazette* of 7 January 1938; his career to date is described in the 21 January issue.

No report series from these three sections are known to survive. Amongst several of chemical interest in the LMS occasional reports is one by A W Hewer "Some war time aspects of laboratory work", 31 December 1942 (BR Record Centre).

F Fancutt was a prolific author on the subject of paint; for example "The Work of the Paint Research Laboratory of the LMS Railway Company", J. Inst. Civil Eng., Vol. 9, 1937-38, pp 140-162, and "The Effects of Different Methods of Pre-treating Iron and Steel before Painting", Iron and Steel Institute Special Report No. 31, 1946. He described "The LMS Paint Laboratory" for the LMS Magazine, 1935, pp 592-594.

W Pritchard contributed an article "The LMS Research Department – the Textile Section" to the LMS Magazine, 1935, pp 66-68. An excellent later account of the work of the Textiles Section is given by C G Winson in the Transport Research Quarterly, no. 5, October 1951 (see chapter 10 below).

CHAPTER 10: THE FORMATION OF BRITISH RAILWAYS' RESEARCH DEPARTMENT

From this point on, Sam Wise is writing at first hand.

The report of the Stanier Committee "British Transport Commission: Report on the Organisation of Research" is held as PRO AN 8 11. His fellow committee members were Sir Charles Goodeve FRS, Dr H L Guy FRS, Sir Thomas Merton FRS and Mr R A Riddles. Secretary was A C Edmonston.

The appointment of Dr Merritt is noticed in *The Railway Gazette* of 13 May 1949.

The six issues of the Transport Research Quarterly (October 1950 to January 1952) are held as PRO ZPER 147 1-6.

Dr Merritt's departure and the appointment of Mr C C Inglis are reported in *The Railway Gazette* issues of 5 and 19 October 1951 and 2 and 14 November 1951.

The organisation of the new Research Department is described in two headquarters-issued documents: "Memorandum of Services provided by the Railway Executive's Research Department", January 1951 (PRO AN 88 88) and "Guide to Internal Procedure", October 1951 (BRB Records Centre). T M Herbert also described the arrangements in his publication "The Development and Functions of the Research Department of the Railway Executive", Proc. Inst. Civil Eng., Part 1, Vol.

2, 1953, pp 220-243 (the Unwin Memorial Lecture 1952). His letter to all staff of December 1950 also survives (AOG's collection). A one-page article on the new department appears as "Scientists behind BR" in the British Railways Magazine, 1952, p. 182.

The departure of Johansen is noted in *The Railway Gazette* of 11 November 1949. The quotation from T M Herbert on loss of staff is from his Half-yearly Report of June 1950, already cited (see chapter 6 above).

The Operational Research Division was formed from the old LMS General Research Department whose creation is noted in *The Railway Gazette* of 1 February 1946.

CHAPTER 11: BR RESEARCH – THE FIRST FIVE YEARS

For the new Department, T M Herbert instituted technical report series coded C for Chemistry, E for Engineering, M for Metallurgy, etc. Those surviving are held at the Public Record Office, as follows:

E series (Engineering)	AN 139 1-556
O series (Operational Research)	AN 142 1-31
VT series (Vehicle & Track)	AN 143 1-30
Ph/F series (Physics)	AN 145 1-59
C series (Chemistry)	AN 149 1-111
M series (Metallurgy)	AN 152 1-50

No reports are known to survive from the series P (Protective Coatings) or T (Textiles).

The Minutes of the Research Superintendents' Committee survive from 1951 to 1956 as PRO AN 97 174-5. These Minutes preserve the text of Annual Reports prepared for the Research Advisory Council at the end of 1951, 52 and 53. Finished reports for the first half of 1950 and for the complete year 1955 are at the BR Record Centre.

Minutes of the Research Advisory Council (1949-1962) are held at the BR Record Centre; those of the Research Coordinating Committee (same date range) are divided between PRO AN 97 171-3 and the BR Record Centre.

Two typescripts describing the 1952 status and history of the Metallurgy Division survive: "History of Metallurgy on BR" dated 16 January 1952 by E D Knights and "The Metallurgy Division of the Railway Executive Research Department" dated August 1952 but unsigned (both at BR Record Centre).

A small booklet "British Railways Research", undated, is preserved (BRB Records Centre) describing the work of the Department. On internal evidence, it can be dated to 1954.

Updated editions of the documents "Memorandum of Services provided by the British Railways Research Department", and "Guide to Internal Procedure" were issued in September 1954 (BR Record Centre).

The Minutes of the Technical Development and Research (later Technical) Committee are held as PRO AN 97 290-2, with supporting papers in AN 97 293-303.

Loach's interest in Ride Index was later expressed in: J C Loach "A New Method of Assessing the Riding of Vehicles and Some Results Obtained", J. Inst. Loco. Eng., Vol. 48, 1958, pp 183-240.

CHAPTER 12: BR RESEARCH 1956-1960

The Modernisation Plan was published by the British Transport Commission as "Modernisation and Re-equipment of British Railways", 1955.

The sequence of Annual Reports to the Research Advisory Council continues, covering the years 1956, 1957, 1958, 1959 and 1960; these provide information on organisational changes as well as technical progress (BR Record Centre). For authorisations, the minutes of the TD&R Committee are valuable (PRO AN 97 290-2).

The document "Services provided by the British Railways Research Department" was revised and re-issued in July 1957 and again, but for Chemical Services only, in March 1960; the "Guide to Internal Procedure" was re-issued in March 1961 (BR Record Centre).

The work on diesel exhaust pollution was reported internally in C83 “Exhaust gas and smoke emission from diesel locomotives”, June 1958, PRO AN 149 26. The physical and chemical testing of sump oils is described in S Bairstow “Control of Quality of Crankcase Lubricating Oils of Locomotive Diesel Engines in Service”, J. Inst. Loco. Eng., Vol. 51, 1961, pp 99-112. The spectrographic work was first described by P T Corbyn “Experience on British Railways with the Spectrographic Examination of Used Engine Sump Oils”, paper to the second meeting of the Inst. Mech. Eng. Lubrication and Wear Group, Newcastle, February 1963. More accessible is P T Corbyn and A F Haines “Spectrographic examination of diesel engine sump oils”, *The Railway Gazette,* 18 June 1965, pp 479-482.

The wagon braking work is well described in T Baldwin, D W Peacock and B T Scales “Problems Arising with Continuously Braked Trains”, Inst. Mech. Eng. Convention on Railway Braking, September 1962. A limited mention of the marshalling yard work is given by D L Turner in his paper “Hydraulic Buffers – a new Factor in Wagon Design”, J. Inst. Loco. Eng., Vol 47, 1957, pp 75-90, citing his own internal report E 112 of November 1955 (PRO AN 139 107). His later report E 188 “The design of modern marshalling yards” of May 1958 (PRO AN 139 179) analyses the fundamental problem with these yards, deriving from the inconsistent free running of wagons.

The Elliott car was authorised by the TD&R Committee on 9 February 1956 (although the authority had to be raised later) and the Research computer on 12 July 1957 (PRO AN 97 290,1).

D Lindsay’s original design for the important “F7” pre-stressed concrete sleeper is given in E 219 of April 1959 (PRO AN 139 208) – one of many reports on this subject in the E series. The first of a series of reports dealing with track loading at a rail joint is J C Loach’s VT 28 “The measurement of dynamic loads on rails following rail joint with particular reference to loads caused by axle-hung motors in electric stock”, January 1960 (PRO AN 143 28). The work on rail-end stresses is described in S Wise, D Lindsay and I G T Duncan “Strength of Rails with particular reference to Rail Joints”, Proc. Inst. Mech. Eng., Vol. 174, 1960, pp 371-407.

Approval in principle for the new engineering laboratory was given in British Transport Commission minute 12/69 of 19 February 1959 (PRO AN 85 12).

The transfer out of the Operational Research Division is shown in the Annual Report to the Research Advisory Council for 1958.

The opening of the new Chemical Laboratory at Muswell Hill was reported in *Chemical Industry* 26 March 1960 and *Engineering* 1 April 1960.

The outline history of the Electrical Engineering Research Section can be traced in the Minutes of the TD&R Committee (PRO AN 97 290-292). The Willesden laboratory is described in a typescript “Report on the construction of the electrical testing laboratory at Willesden” dated April 1958 (BR Record Centre).

The 1960 re-organisation is described in the 1960 Annual Report and in the “Guide to Internal Procedure” of March 1961. One consequence is that the metallurgy and physics work is now reported in the E series, the M and F series ceasing.

The retirement of T M Herbert on 30 April 1961is noted in *The Railway Gazette* of 12 and 26 May 1961.

CHAPTER 13: BR RESEARCH FROM 1961 – A NEW ERA DAWNS

For the 1960 internal re-organisation, see above chapter 12.

F Fancutt’s retirement is reported in *The Railway Gazette* for 21 July 1961.

A full description of the Paddington laboratory was published by the British Transport Commission: “The Soil Mechanics Laboratory of the Western Region”, undated, but circa 1958 (BR Record Office).

Dr Sydney Jones’ appointment is reported in *The Railway Gazette* for 2 and 16 March 1962.

The transfer-in of Soil Mechanics and Electrical Research and the splitting of Chemical Services were put to the British Railways Board by John Ratter and approved at their meeting on 10 January 1963 (BR Record Centre).

Papers relating to the re-organisation of Protective Coatings and Textiles are held in Scientifics Ltd. Archive DA 86 and DA 123 respectively.

The appointment of Dr Spring is noticed in *The Railway Gazette* of 24 May 1963.

The process of authorisation of the new Engineering Laboratory can be followed in the British Transport Commission Minutes from 19 February 1959 (authorisation in principle), through 19 March, 27 August 1959, 28 April, 23 June 1960 to 27 April 1961 (Ministry of Transport approval) (PRO AN 85 12-16). Technical Committee minute of 23 September 1960 is also relevant (PRO 97 292).

The opening of the new Engineering Research Laboratory is reported in *Engineering* for 29 May 1964 and in *The Railway Magazine* for July 1964. The large fatigue testing plant had been described in *Engineering* for 15 May 1964. The detailed Administration Instructions for the opening ceremony survive; also the BR Chief Architect's landscape-format "Description of the Building" produced for the occasion (BR Record Office). The next week's events are detailed in "British Railways Board Research Department, Engineering Research Division, Open Days Programme, Thursday and Friday 21 and 22 May 1964" (AOG collection).

From 1963 to 1967, annual or 6-monthly Job Progress Reports were issued by the Chief of Research (latterly by the Headquarters Research Manager) listing progress on all current jobs (BR Record Centre). The first three are relevant to this period: "Job Progress Report period ending December 1963", "Job Progress Report No. 2 (January-June 1964)" and " Job Progress Report No. 3 (July-December 1964)".

Papers relating to the re-opening of the London Road laboratory (now Hartley House) are held in Scientifics Ltd. Archive DA 93; see also "British Railways Board Research Department, Regional Scientific Services Division, Opening & Open Days, 20 & 24/25 November 1964" (AOG collection).

The Chemical Research Division commenced its CR report series (PRO AN 148 1-54) in December 1962.

The story of vehicle stability, with sources, is told in A O Gilchrist "The long road to solution of the railway hunting and curving problems", Proc. Inst. Mech. Eng., Vol. 212(F), 1998, pp 219-226.

A description of the state in 1962 of the computational work is given in P J Coates "The use of computers in railway engineering", J. Inst. Loco. Eng., Vol. 52, 1962, pp 239-253. The work on fatigue is described in S Wise and E S Burdon "The dual roles of design and surface treatment in combating fatigue", J. Inst. Loco. Eng., Vol. 54, 1964, pp 142-177. The design code for axles is Traction and Rolling Stock Department Instruction T 72, E Scott, July 1967.

Reports on the fundamentals of ballast behaviour only started to appear in 1967, see M J Shenton "Repeated load tests on granular materials, part 1", report S&CEP 6, 5 January 1967 (BR Record Office) and D L Heath and M J Shenton "Behaviour of track ballast under repeated loading conditions", report E 610, May 1968 (PRO AN 139 522). The work on cross-girder connections was also reported in 1967, see P West and W Partington "Behaviour of standard cross-girder connections in steel underbridges under repeated loading", report E 598, April 1967 (PRO AN 139 511).

Noticed in *The Railway Gazette* are: the retirement of Mr C C Inglis (issues of 7 August and 4 September 1964), the departure of D L Bartlett (issue of 6 November 1964), and the appointments of Dr R W Sparrow (issue of 18 September 1964) and Mr S F Smith (issue of 19 March 1965).

The Electrical Research Division's report series are EL (PRO AN 147 1-82), commencing January 1963, and an overlapping series ELD (PRO AN 150 1-193) commencing in October 1965.