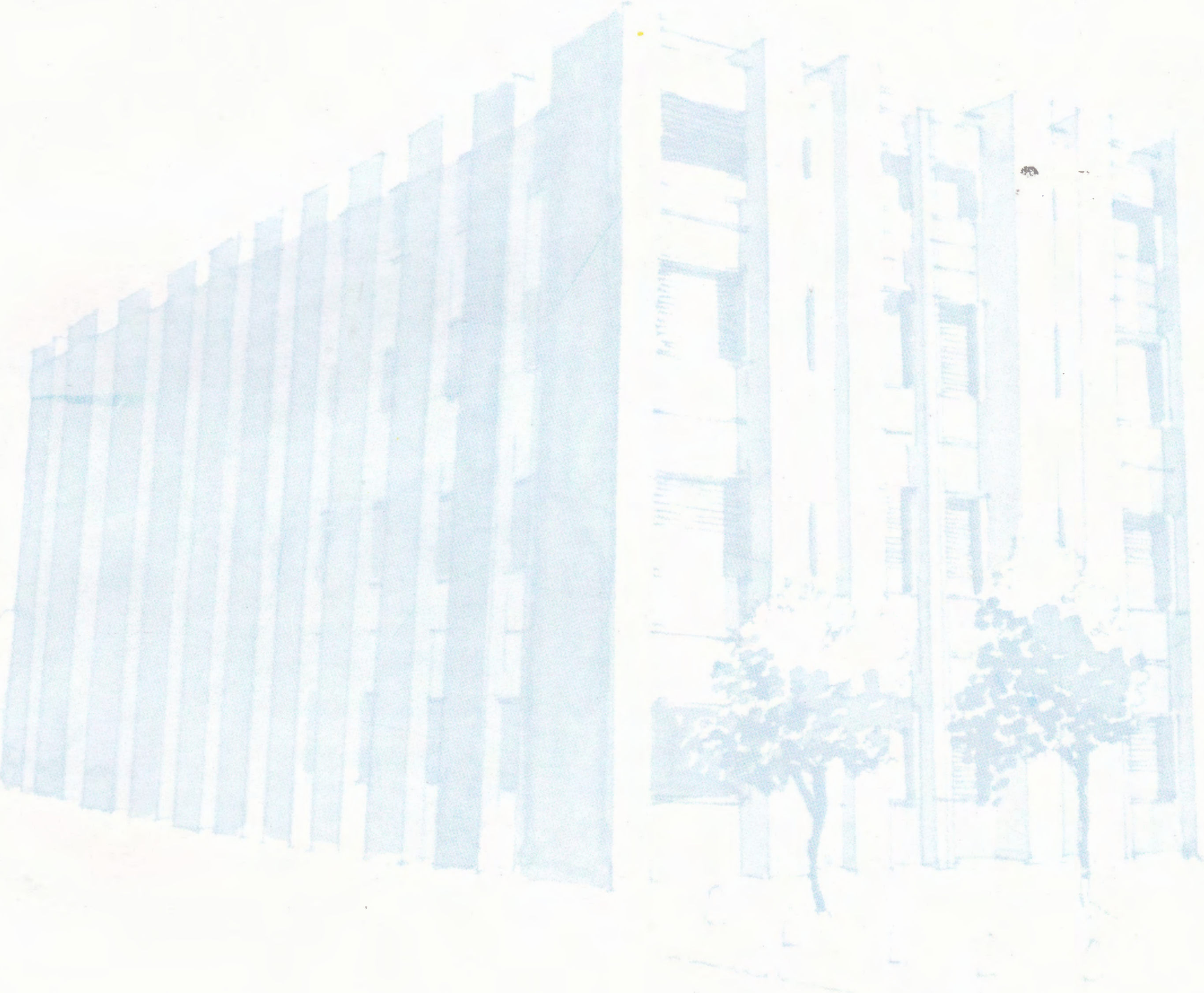
History of the
London Research Station
1924 - 1993



BG Technology

Gas Retired Employees Association, London HQ Branch

History of British Gas Research Stations

British Gas was for many years a major world gas company. A large part of its position was its activities in research and development (R & D).

There were five research stations

- Engineering Research Station (ERS)
- London Research Station
- Midlands Research Station
- Watson House
- On Line Inspection Centre (OLIC)

In 1995 at a time of major change in the structure of R & D, British Gas Technology published histories of the four of the research stations of British Gas. Unfortunately, there was no similar history published of OLIC although it is partially covered in ERS report.

This document is one of those histories.

These documents were never put into the public domain even though they were fascinating records of a key part of the gas industry. A full set of the reports was made available by Eric Francis, a former Director of the Midlands Research Station and the London HQ Branch of the Gas Retired Employees Association decided to fund their scanning so that they could be put into the public domain.

The London HQ Branch of the Gas Retired Employees Association is an organisation of British Gas pensioners who worked for all or part of their careers at the London headquarters of British Gas

At the time of publication of the reports British Gas had moved its R & D, renamed Research & Technology (R & T), to Loughborough.

When British Gas plc demerged in 1997 into BG plc and Centrica plc, R & T stayed with BG plc.

In 2000, a further demerger of BG plc took place into BG Group plc and Lattice plc. Lattice included Transco, the UK gas transportation company, and Advantica Technologies, the new name for BG Technology.

In 2002 Lattice merged with National Grid. At about the same time Advantica bought Stoner Technologies to broaden its reach to the US and to prepare the company for sale.

In 2007, Advantica with its 660-world staff was sold to Germanischer Lloyd.

In 2009, Germanischer Lloyd merged with Noble Denton to form GL Noble Denton and in 2010 they sold the equipment testing business inherited from Advantica to BSI.

Finally (?), in 2013 GL Noble Denton merged with DNV (Det Norske Veritas) to form DNV GL. DNV GL has a turnover of about £2 billion with around 14,000 employees world wide of whom about 1,000 are British. There is still an office in Loughborough.

OLIC has gone in a different direction. It was sold to GE and remains in Cramlington where there is the world headquarters of PII Pipeline Solutions a 50:50 joint venture between GE Oil & Gas and Al Shaheen

Holding, a wholly owned subsidiary of Qatar Petroleum. It has 11 locations globally and employs over 650 people.

While it is true that the vestiges of British Gas R & D survive after all these mergers we must ask why did it decline so dramatically?

The answer broadly lies in the competitive gas market which in Europe at least was initiated in the UK. Before this the world thought, and in parts still does, that gas was a natural monopoly; gas on gas competition was inconceivable, even illogical. That was the gas industry view, but politicians thought otherwise. In fact, the only part of the gas chain which is a natural monopoly is transmission and distribution.

British Gas as a nationalised monopoly industry could have a long-term perspective and some blue sky thinking to drive the industry forward in strong competition with the electricity industry and to a lesser extent oil. Technology was at the heart of this and the industry was more or less left to invest in R & D without external financial pressure and with a captive customer base to fund it.

If we look at the three demerged elements of British Gas plc in the context of our liberalised gas market, we can see how different the R & D demands are.

BG Group focussed on exploration and production and latterly became an extremely successful player in the LNG market. So successful that Royal Dutch Shell took them over. In terms of R & D the last BG Group annual report shows R & D at $33 million of which $19 million was with Brazilian third parties. Quite a contrast to the internal R & D with British Gas.

National Grid Gas Transmission has a continuing need for R & D support but is limited by the regulator OFGEM as to what expenses can be passed through in customer charges. For example, the most high-profile research currently is Project GRAID (Gas Robotic Agile Inspection Device). This is a National Grid project in conjunction with three British Small Medium Enterprises (SMEs) to develop ways to accurately assess the condition of its pipework assets that cannot currently be inspected via conventional Pipeline Inspection Gauges (PIGs). It secured £5.7m of Ofgem funding.

The third element is Centrica, the marketing company. Much R & D for marketing by British Gas plc and its nationalised predecessors was to compete with electricity. It also was a monopoly. Now Centrica through its British Gas brand sells electricity as well as gas so why should it spend on competing with itself? The other is that any developments funded by Centrica to improve gas could be taken up by its competitors. So, the type of R & D funded in the past is no longer economically viable.

In conclusion, the gas R & D landscape has changed remarkably since the 90s. However, we must not let the past be forgotten. It is right to celebrate the real achievements of British Gas and its predecessor companies. The publication of these reports is part of that celebration.

Rowland Sheard
March 2018

BG Technology

History of London Research Station

1924 - 1993

HISTORY OF LONDON RESEARCH STATION
1924-1993

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Foreword to Parts 1 and 2

This is an historical account that traces the development of the London Research Station from its humble beginnings in 1924 until 1993, when its activities were brought to an end at Fulham and incorporated into the new Research Station of British Gas at Loughborough. The history of a research station can be written from various viewpoints, and for this reason this book is divided into two parts.

The first part is mostly about people, the buildings they occupied, the conditions they worked in, and the adventures that befell them. Special activities undertaken in the Second World War are described in this part, but otherwise reference to the work of the Station is made only where it is necessary to illustrate an anecdote or the working conditions at the time.

Inevitably, many who deserve mention have been left out, not by intention but because records are no longer intact, and memories are poor substitutes. Furthermore, many who contributed much to the stature and success of the Station left no legacy of remarkable incidents to be unearthed and amplified in a narrative such as this. In this respect the account is incomplete and selective. But it is hoped that sufficient has been included to remind those who have taken part, and others who observed at a distance, what it was like to live and work in the establishment that is remembered, hopefully with affection and some pride, as the LRS.

An inconsistency will be found, particularly in Part 1, in the manner of addressing individual staff. In places individuals are referred to formally by surname: elsewhere, first names or even nicknames are used. In part this reflects the change in formality that occurred within the Station as the years went by, resulting in the increasing use of first names - even with respect to the Director. Also, the male gender is used in this narrative for grammatical convenience only. All general references to staff, derogatory and otherwise, apply to both sexes.

Part 1 draws heavily on the booklet "Sketch of Laboratory Life", up-dated as necessary, that was produced in 1978 by Peter Graham and Joe Gooderham as part of the celebrations to mark the fiftieth anniversary of the establishment of a research laboratory on the Fulham site.

The second part of the book gives an outline of the work of the Station from its early days until its closure in 1993. It too is based on a publication produced on the occasion of the Station's Golden Jubilee, namely the paper "Fifty Years of Research at Fulham", by Graham Cribb who presented it in 1978 to the 44th Autumn Meeting of the Institution of Gas Engineers (Comm. 1069). This described the work of the Station up to that time. Much of this paper has been reproduced as written, but here again it has been brought up-to-date as necessary.

PART 1 - WORKING AT LONDON RESEARCH STATION

1.1 Introduction

British Gas is a Company that employs the very latest scientific and engineering techniques. Its activities form an integral part of the energy scene, and the manner of its future development will influence the availability of energy resources and their utilisation in the twenty first century. Not surprisingly, in such an industry research and technology is a highly structured and organised activity. The work in the research establishments of British Gas is closely geared to the immediate and future needs of the company by a complex system of programme planning and development which is integrated into the committee structure that controls the operations of the Industry.

In such an environment the activities of the Research Stations are monitored and disciplined by a wide range of people drawn from all the Industry's functions. In other words, research and technology is very much a part of the day-to-day business.

But it was not always so. At the end of the First World War the gas industry was composed of hundreds of undertakings, some private companies, others under the control of local authorities - all of them making, purifying, and distributing gas by techniques that were basically up to one hundred years old. Such techniques had been gradually refined, and here and there successful attempts had been made to put them on a scientific footing. The Gas Regulation Act of 1920 was a big factor in encouraging the gas industry to become more scientific. This Act required gas to be sold by its calorific value rather than its volume, thereby enabling the Industry to disregard the luminosity of gas as a criterion of quality. Not surprisingly most progress had been made by the biggest companies, the largest of which, The Gas Light and Coke Company, supplied gas to a large part of the London area, mostly north of the Thames, and to parts of Essex.

1.2 Sir David Takes a Hand

In 1924 the fortunes of the Gas Light and Coke Company were largely under the control of Sir David Milne-Watson, who was its Governor, and Thomas Hardie its Chief Engineer - men who in retrospect are acknowledged as giants in the history of the gas industry. Elected Governor in 1918, Milne-Watson set about rejuvenating the Company after the war. Having sorted out the financial and other aspects of the business he turned his attention to the gas supply system. His plans for a fully integrated system based on larger and more efficient works operating new processes would demand scientific knowledge beyond the capability of the few station chemists.

The First Steps

As a first step Milne-Watson went back to his old college, Balliol, sought out his former colleague, Brigadier Harold Hartley, newly returned from his war service as Head of Chemical Warfare, and persuaded him in 1922 to join the Court of Governors of the Gas Light and Coke Company to advise on scientific matters.

An early observation of Harold Hartley was that the centre of gravity of the research at Beckton was wrong in that there was a research laboratory on the Products Works rather than in the Gas Works. The first step towards rectifying this situation was the appointment of Harold Hollings, as Chief Gas Chemist, on April 1st, 1924, and the setting up of a new laboratory at Horseferry Road.

Harold Hollings

Harold Hollings was born in 1892 and educated at Archbishop Holgate's Grammar School. In 1909 he entered Leeds University, where he held the Gas Research Fellowship, and where his work under Professor Cobb included studies on the decomposition of methane. In 1914 he won an 1851 Exhibition Research Scholarship for post graduate work on the Continent. The outbreak of war forced him to relinquish this and, after working in chemical factories, he entered the South Metropolitan Gas Company and later became Senior Gas Chemist. There he worked under Charles Carpenter, who was an outstanding gas engineer at the time.

Horseferry Road

On 1st April 1924 Dr Hollings set foot for the first time in an entirely new but makeshift laboratory that was built on the top of the Rental Department in Horseferry Road, Westminster, the old headquarters of the Gas Light and Coke Company.

The laboratory was not very grand. There was a library and a study, a balance room, an office for Dr Hollings, one for his secretary and another for a shorthand typist. At one end of the oblong laboratory there was a trap door in the floor which led down steps to a storeroom for chemicals and apparatus.

To Dr Hollings the first impression presented a bleak prospect. It was clear that no thought had been given to a programme of work, his responsibilities were only loosely defined, and he had inherited numerous files of miscellaneous papers and documents of doubtful value. On arrival home that night he confided to his wife that he thought he had made a big mistake in accepting the job.
In the first few weeks it became apparent to him that he was not only in charge of the research laboratory, but was also responsible for numerous works laboratories scattered throughout the area of the Company.

The First Programme

In July Dr Hollings was summoned to the presence of Sir David and Thomas Hardie who sought his opinion on the status of various aspects of gas works processes and plant. An account of this meeting is given in Part 2, which gives an indication of the casual way in which a programme was formulated to determine the work undertaken by the laboratory, and to lay the foundation of a research programme that was to stretch up to the years of the Second World War and beyond. As time went by further conversations of this kind modified and shifted the direction of the research undertaken by the laboratory. By such a process in those days was the programme planned and put into effect.

Early Staff

By April 1925 the staff consisted of Hollings, Holliday, Exell, Eaton, Banks, Pexton and Gooderam. Gosling and Rowell were the two laboratory assistants, and Miss Blackett and Miss McKenzie were Dr Hollings' two secretaries. Shortly afterwards the list of graduates was added to by the arrival of Griffith, who in 1952 was to succeed Dr Hollings as Controller of Research, and Hutchison, who eventually was to become Deputy Chairman of the Gas Council, an achievement which, in later years, was to be often quoted to staff as proof that it was possible to rise from the laboratory into high office. In 1926 five chemists joined the complement from the products works. They were Siderfin, Lewcock, Voss, Ravald and James.

1.3 A New Laboratory

Sir David had always considered that the laboratory at Horseferry Road was a temporary measure, and that eventually better purpose-built premises would be required for the new research function. In any case, the laboratory at Westminster was too small for the expanding team, and Hollings had to deploy his staff on various works whilst consideration was given to the siting of the purpose-built laboratory.

At one stage Beckton was seriously considered as a site for the laboratory as an alternative to Fulham. Hollings rationalised the selection of Fulham by pointing out that the Station would soon have two types of continuous vertical retorts as well as horizontal retorts and water gas plants. It was also more accessible to the London libraries and the learned institutions. But there is an alternative version of how the decision was reached. In Sir Harold Hartley's Address to the Centenary Meeting of the Institution of Gas Engineers in 1963, "Memoirs and Personalities"(2), he recalled how the long discussion on the new research laboratory ended one day at Fulham when David Milne-Watson waved his umbrella at the dilapidated horse stables and said 'That's where we'll build our research laboratory'.

Dr Hollings soon became closely involved with the architect, Walter Tapper, in drawing up specifications for a new building, and in March 1925 plans were submitted to the Works and Products Committee of the Company for the erection of the laboratories at Fulham on the site of the old stables. The new building was designed in a majestic style. Walter Tapper was insistent that despite its industrial purpose and the dinginess of its surroundings it should not lack dignity either inside or out, and he went to great pains on details such as the concealment of all internal services. At the time it must have looked a little out of place at the entrance of Fulham Works. It had three main floors and a fourth half-storey at the top which housed the library and a room for the librarian. The main laboratory on the top floor was called No. 1 Lab. It had four large bays with generous bench space. It also had four large fume cupboards and a balance room. There was a lift at one end connecting the laboratory to the first floor, to a rear goods entrance, and to the basement. At the other end were two offices, one for Dr Hollings, and one for the two clerical staff who dealt with orders, typing and other paperwork.

The laboratory had a high ceiling and large windows which could be opened with a long-handled key. Heating came from radiators fitted under these windows. Although such a large laboratory had its faults it was at least airy which probably reduced the risk of mercury poisoning. The second floor consisted of No. 2 Lab, a works laboratory, and a workshop. The basement had several smaller rooms containing laboratories, stores, boilers, a vacuum plant, and a switch room.

The Opening

The formal opening of the laboratories on Thursday, 26th July 1928 was a splendid affair. It was preceded by a luncheon at the chief offices of the Company in Horseferry Road, at which Sir David entertained a gathering of distinguished personalities from local government, the civil service, industry, and the universities. After formal speeches the assembly motored to Fulham where Sir Richard Threlfall, Chairman of the Fuel Research Board, ceremoniously unlocked the door of the building, thereby officially establishing the laboratories on the Fulham site. In fact work had been in progress there since the January of that year.

The event went smoothly except for one minor hitch, of which the visitors became aware only on their departure. Dr Hollings had, of course, attended the luncheon, and it had been arranged that Dr Pexton, his deputy, would be stationed inside the entrance to greet the visitors as they entered the building, and play a major part in conducting them around. As the door opened, he stepped forward somewhat nervously to perform his duty. Sir Richard, who was first through the door, mistook Pexton for some kind of doorman and, before a word was uttered, promptly handed Pexton his top hat and walked on past. The others, streaming in close behind, followed Sir Richard's example and to Pexton's bewilderment he quickly found himself struggling with an armful of top hats with no idea of their ownership or of what to do with them. Needless to say as the proceedings ended there was much confusion and some loss of dignity as the owners tried to identify and recover their headgear.

Expansion of Staff

In the years that followed the opening of the new building more young graduates arrived, mostly from Oxford University channelled in by Sir Harold Hartley. Among these were Badger, Donnelly, Bruce, Garstang, Hopton, Crawley, Newling and Zvegintzov. Others came from the Royal College of Science (as had Silver and Gooderham) in the shape of Hill, Haffner, Weston, and Maccormac. Burns came from Cambridge, while other universities supplied Morcom, Plant, Bispham, Chaplin, Spivey and Taylor. There were many young chemical assistants such as Dryden, Newman, Patrick, Scott-Wilson, Dudden, Pringle, Higginson, Thorndycraft, Craddock, Bagg, Cartwright, Inman, Chapman, Gladstone, Daroux, Hughes, Johnson, Longley, Lewis, Read, Reid and Jessel. Many of these were studying frantically for their degrees, and some obtained qualifications with triumph. One, for example, got a first class degree in chemistry and also a second class for physics.

Although perhaps they were not aware of it at the time, these were pioneers not only in setting up a research laboratory that was to last for much of the rest of the twentieth century, but in establishing chemical engineering research as an essential component of industrial progress. In listing their names a feature emerges: they were all men. Women were to find a place, and make their mark, in industrial research in the gas industry - but that would come much later.

Conditions of Service

What was it like to work in the Fulham laboratories in those early days? Perhaps the best idea would be to let one of the staff of that time, "Joe" Gooderham, describe it in his own words.

"We were a very happy band. We were all young men bursting with energy, ideas and enthusiasm. We survived fires, the spilling of acids and alkalis, explosions, and other minor catastrophes. We worked liked beavers, sometimes all night as well as all day and every Saturday morning too. We had two weeks holiday a year, and in 1937 our salaries were: Chemists, Class 1 £135-250 p.a.; Class 2, £265-350 p.a.; while Chemical Assistants got 31/- per week at age 18, 38/- at age 20, and 58/- at age 21. An increase of £10 per year was phenomenal and meant a personal interview with the Governor. You could, however, get a three course lunch for 1/4d. We had our lighter moments. We had our own Chemical Dinner each year, and made our own entertainment with our own plays and music. When a colleague got married we sent him and his bride a special telegram. One sent to Banks merely said 'Prosperity always comes to the Banks'. To Weston we sent a poem, the last two lines of which were: 'And may Good Fortune always rest on the old historic name of Weston.'

"I recall a number of happenings at Fulham. There was the incredible sight of one Chemist soundly asleep two feet away from a tricky distillation of benzole over a naked gas flame. There was the smart de-bagging of Newling when the top of a Winchester quart broke and emptied the entire contents of concentrated sulphuric acid down his trousers. There was the extraordinary bleaching effect of bromine on the red hair of Pringle, and the case of Dudden who got nitrogen peroxide in his eye. We washed it out immediately but, as a precaution, took him to a famous eye hospital. There the doctors at first refused to believe there was any such thing as nitrogen peroxide; then they panicked and kept the patient unnecessarily in hospital for a week.

"We played tennis, cricket, and indoor games together, and we played to win. We used to play two cricket matches per year - one against the works and one against Watson House. Amusing accounts were written about the games. Sometimes the Fulham and Watson House versions did not appear to be about the same game. Some memorable performances included Wilson's famous over in 1941 - three wides, four no balls, and still a maiden over. Estall bowled splendidly in 1950 but only after he took his boots off.

Prattley held five catches in the deep in 1949, with the queer technique of clutching them to his bosom. Tatham arranged his field in 1949 like a true chemist in the form of a benzene ring. Mary Seaton played a few times and did particularly well against Watson House in 1954. They took off their fast bowlers like gentlemen when Mary appeared, but they did not know that she played cricket regularly.

"One of the most valuable men at Fulham was Shail, a super craftsman. He and his mate, Lister, could make anything in metal, while the craftsmen in the Carpenters' Shop on the Works could make anything in wood. We chemists and our assistants, together with Shail, Lister and the carpenters, made most of our apparatus to our own designs. Later the Board's workshops made the prototype pilot plants. Except for really intricate work, the glass blowing was home made. Some of us became quite expert.

"Many of us used to be evening lecturers at places like Westminster Technical College and Chiswick Polytechnic, who ran special courses on gas technology. Craddock, Reid and I used to give a two-year course on the 'Technical Chemistry of the Gas Industry', and many of our pupils later became big shots in the gas world."

Keeping up with Scientific Progress

In any research laboratory it is difficult to keep pace with scientific progress, and although in those early days the volume of literature was less than it is now it was still quite a problem to keep in touch. The Librarian, first Voss and then Miss Potton, used to circulate scientific journals amongst the staff. Each was allocated a few, and it was his job to read or skip through them and to draw the attention of his colleagues to various articles of interest. Between them the staff managed to cope with many foreign languages, and to keep reasonably up to date with scientific progress. Staff used to go also to the libraries of the Patent Office, the Chemical Society, the Science and British Museums, and learned how to sniff out anything of interest or relevance to their work.

But there were few committees to attend and no such things as liaison officers and programme managers. These were to come later. The Xerox machine or the like had not been invented, and such copying processes that existed were too troublesome or cumbersome to bother with. The organisation was straight-forward and un-cluttered, and there were few impediments to or distractions from the pursuit of scientific and technical studies.

Working Off-Site

Much of the work of the Fulham Laboratory was done away from the site either on, or associated with, manufacturing and purification plant. Staff had to be prepared to work on any of the Company's (later the Board's) manufacturing stations, often for long periods. Since these extended from Southend-on-Sea to (eventually) Ascot, and for many years the only means of travel was a bicycle or public transport, the requirements could impose considerable strains on enthusiasm and morale. Furthermore, these strains were seldom eased by relaxations in the strict rules applying to such travel. For instance, when Skelton and Reid had to work at Southall for a time they found it much quicker and more convenient to travel by Greenline bus. Later, when close examination of their expense claims disclosed this fact, they were taken severely to task and required to refund the difference between the price of this grand mode of travel and the ordinary fare.

The Works Laboratories

Contacts with the operations of the industry provided no problem and were simply achieved. In 1937 the Gas Light and Coke Company represented in size 1/6th of the entire British gas industry. Its 13 manufacturing stations employed plant that collectively represented a fair cross section of the major processes available then for the production of gas. Each had a works laboratory that came within the responsibilities of Dr Hollings, and by this means, and the maintenance of good liaison with the engineering function, ready access was available for such field studies as were necessary.

In earlier years the structure and resources of works laboratories varied considerably. Some were splendid, like those at Beckton and Fulham, but others were improvised and rather tarry and smelly. Each had its own graduate chemist and staff who, in addition to the routine duties required by the works operations, carried out from time to time trouble shooting and other support studies, some of which were duly reported and recorded in the chemical laboratory records at Fulham.

The supervision of these works laboratories and their staff represented a considerable responsibility for the Director of the research laboratory. For instance in 1953 there were 21 works laboratories staffed by some 180 chemists and assistants, which amounted to over 3 times the number of scientific staff then at Fulham. As time went on there was a small but significant transfer of staff between these laboratories and the research laboratory. By such means the staff of the latter were able to keep their feet firmly on the ground.

1.4 The War Years

With the coming of the Second World War the staff at the laboratories carried on their normal work for a while, but in time various war-orientated tasks were undertaken.

Bomb Damage

One problem resulted from the damage to gas mains caused by bombing. So many leaks occurred that instead of a district pressure of 4 1/2 inches water gauge the pressure fell in places to about 1/2 inch. Not surprisingly, gas appliances scarcely worked at all. Virtually all the staff stopped research work and, in conjunction with staff from Watson House, descended on London's factories where at each location they persuaded the works manager or technical director to loan several craftsmen. These men were then given the task of enlarging the orifices of each gas appliance so that the burners passed as much gas at 1/2 inch as they would have done at 4 1/2 inches. Not surprisingly the staff had some amusing adventures. At one factory Gooderham asked a workman how he took cover in an air raid. He said he got inside the furnace if it was cold. And sure enough he did, so Gooderham got in too. In another factory in East London Wilson asked the same question. "What's the good of taking cover?" said the workman, "that room is full of gelignite."

Unexploded Bombs

Another unusual job descended on Dudden and Gooderham. A proportion of bombs that fell on London did not explode, but nevertheless left a sizeable crater. The Ministry of Supply sought the advice of the laboratory on whether it would be possible to tell if a bomb had exploded or not by testing the air around the crater. The reply was that provided the wind had not blown all the gases away there would be traces of nitric oxide, sulphur dioxide, and other gases around it, whereas if the bomb had not exploded such gases would be absent. The Ministry asked the laboratory to design an apparatus for use on site, and this was duly done.

Dudden and Gooderham then went to Richmond Park where the Earl of Suffolk and the Royal Engineers were coping with London's unexploded bombs. The Earl would blow up a bomb for them and they would shoot out of cover and suck the gases through the apparatus. It worked splendidly, but if anything the apparatus was too sensitive and would react to the exhaust from a passing lorry. The Royal Engineers used to sit on the unexploded bombs to eat their sandwiches and, not to be outdone, but never with the same peace of mind, Dudden and Gooderham did so too. It was bitterly cold at that time, and the soldiers used to keep warm with the aid of big bonfires which they stoked up with TNT that they had steamed out of the bombs.

The Earl of Suffolk took great care of Dudden and Gooderham, and they were saddened to hear later that he had been killed while gallantly defusing a bomb. By the time the apparatus had been perfected Hitler's wrath was fading, so it was never tried out in anger. Moreover, the Ministry never took charge of the apparatus and for many years after it collected dust in a corner in Fulham.

Benzole Production

A major war task came after the Government had signed an order which demanded all public utility undertakings to operate their benzole plants ."...in such a manner as will extract to the fullest capacity of that plant the crude benzole of such gas so as to yield the maximum amount of toluene therefrom." Just before the war Dudden and Gooderham had been working on benzole and toluene, and a paper had been written on the subject which was not published because it was too informative to potential enemies. The Minister did, however, make use of the laboratory staff and facilities to enforce the order. In the four years from November 1941 to November 1945 the staff concerned visited over 300 gas works in the UK. Normally at each works they would freeze out all the benzole in the gas both entering and leaving the benzole plant overnight. Assistants at Fulham would analyse these two samples for their toluene content, from which the efficiency obtained could be compared with the theoretical figures derived earlier by Silver. If the two figures were not in substantial agreement then something was wrong and corrective measures had to be taken.

They travelled around by train or taxi, or in their hosts' cars, often carrying fives cases of equipment. Gooderham personally travelled over 100,000 miles, usually visiting several works in the course of each trip.

Fog Dispersal

Another important wartime activity in which the laboratory was involved was the operation known as FIDO (Fog Investigation Dispersal Operation). On 26th September 1942 Mr Churchill issued a memo which read:

"It is of great importance to find a means to dissipate fog at aerodromes so that the aircraft can land safely. Let full experiments to this end be put in hand by the Petroleum Warfare Department with all expedition. They should be given every support."

There immediately followed a period of intense activity and a conference of big industrial concerns including the GLCC. Such was the urgency with which the project was tackled that on the evening of 3rd November 1942, not much more than a month after the initiation of the exercise, a successful demonstration of fog dispersal was conducted in the empty Staines reservoir, using coke braziers in the form of horizontal troughs. The Staines reservoir was an excellent site for such tests and it became the major experimental site for FIDO in subsequent months. Eventually the coke brazier system was superseded by the "Haigill" system which employed butane gas and became the main type of installation at airfields. But undoubtedly the early work with coke, in which the laboratory staff were very prominently involved, did much to establish the effectiveness and feasibility of the project.

Hydrogen Production

Barrage balloons became a familiar sight in the sky above war-time London and other towns and cities. They were put there to discourage low flying aircraft whenever there was a possibility of an air raid and, because of the large numbers involved, created a heavy demand for hydrogen for which the supply was scarcely sufficient.

The resources of the gas industry were called upon to play a large part in the expansion of hydrogen production, and Hutchison was engaged on this work, eventually becoming Director of Compressed Gases in the Air Ministry. After consideration of various methods a combination of the water gas and steam/iron processes was selected as the most practicable, and by 1944 72% of the hydrogen required was being supplied from various gas works sites.

At the end of the war the Deputy A.O.C. of Balloon Command was able to say, ."...the successful deployment of barrages.....had never been affected by lack of hydrogen. In fact it might be truthfully said that they were only possible because of the ready availability of the gas."

Badger's Cats Meat

Because of the risks to gas works from air attack, staff were expected to undertake shift work at various stations to help provide a round-the-clock coverage. Badger's contribution to this effort included spells of night work at Brentford to which he used to travel by bicycle. On his way he would call in at a pet shop to collect cats meat which he would store overnight in a fridge at the works, and then take home the next morning for his cat. One of the Brentford engineers at that time had a similar habit, but his parcel of meat consisted of a juicy steak which he obtained "off ration" from some doubtful source, and which he cooked and consumed with relish to comfort him during the night. Needless to say, one morning Badger arrived home to discover that his parcel contained the steak. He hadn't the heart to investigate what fate had befallen his horse meat, except to note that it had disappeared from the fridge.

Dad's Army

The laboratory combined with Fulham Works to form a unit of the Home Guard. Some of the staff did not look very soldierly in their heavy uniforms and big boots, but they tried hard and did their bit. They were, perhaps, not very efficient. Even the Boy Scouts succeeded in a mock raid on the works. Lewis was made an officer and was reported to be very good at it.

But in addition to the special work that resulted from war-time activities much of the normal research went on as usual. After all, the successful continued operation of the gas industry was a vital part of the war effort and the jobs of most of the staff were classified as reserved occupations.

Towards the end of the war some chemical engineers were made instant Captains in the army, and Dr Hollings was made a Lt. Colonel. They were then hustled to the newly-occupied Ruhr and elsewhere to make studies of German chemical plants. After a short spell as Officers they were demoted to some sort of special correspondent.

1.5 Post War Changes

In the months following the end of the war the laboratory settled down to its peacetime activities, and to the prospect of nationalisation. During this time there were considerable staff movements out of the laboratory to works laboratories and to the engineering side of the Industry. Hutchison had already gone to the Air Ministry, as mentioned earlier, and Burns and Haffner had become Station Engineers. Bruce, had left Fulham in 1937 for Westminster. None of them returned to the Laboratory after the war, but all served later as Presidents of the Institution of Gas Engineers and became Area

Board Chairmen. Two of them were awarded the Birmingham Medal. Hutchison (as mentioned earlier) subsequently became Deputy Chairman of the Gas Council in 1960, was knighted in 1962 and elected a Fellow of the Royal Society in 1966.

Staff who moved from Fulham at the end of the war included Stripp, Dudden, Clifton, Thorndycraft, Weston, and Bispham, while notable acquisitions included Densham and Noble from Watson House.
In 1946 the work of the laboratory was organised into four groups, although some members of staff were concerned with the work of more than one group:

Group I: Catalytic work with particular emphasis on the removal of sulphur compounds from gas (Badger, Densham, Marsh, Newling, Plant, Voss).

Group II: Removal of H_2S from gas, particularly by iron oxide (Crumley, Hopton, Newling, Plant, Silver).

Group III: By-products, e.g. purification of naphthalene and phenol, and the production of new materials for plastics manufacture (Badger, Densham, Gooderham, Lewcock, Plant, Ravald).

Group IV: Miscellaneous, including carbonisation tests, the production of peak load gas, and the testing of refractories and paints (Chaplin, Lewis, Maccormac, Spivey, Newling).

At this time the scientific staff numbered about 40 of whom 17 were graduates.

Expansion

The 1927 building had been constructed with the idea that at some future time it would be extended, and the finish of the southern end of the building was left in a somewhat crude condition in anticipation of such an expansion. A speculative drawing of a possible extension was produced, but the prospect of any elaborate development was abandoned by the decision in 1948 to construct a single storey prefabricated Marley building for the princely sum of £2,700. This annexe, which became affectionately known as the "giraffe house", was officially designated number 4 Laboratory, and provided much needed indoor accommodation for pilot plant work.

A year later a building on the Wharf in Fulham Works that had previously been used for the manufacture of active carbon was handed over to the laboratories for large scale development work, and was described thenceforth as No. 5 Laboratory until its use by LRS was discontinued in the mid fifties.

The next major extension of laboratory space occurred in 1952 with the construction of a mezzanine floor in the 1927 building to house offices and a design office. Also in that year an air-cleaning system was installed in the main building to provide 6 air changes per hour at a temperature of 68 degrees F. Further space became available two years later when the Fulham Works laboratory staff moved into new laboratories, thereby liberating No. 3 Laboratory for research work.

It is a coincidence that the second major development of laboratories at Fulham was to take place, like the first, on a site formerly occupied by stables. But in this case the original building was retained and formed part of the development. This expansion, which was completed in 1955, involved the conversion of the stables building to laboratories and workshops, and the construction of an airy pilot plant building which was attached to, and designed to blend with, the existing building, thereby forming an L-shaped complex subsequently known as the 1955 Building. This extension, which was formally opened on the 18th November 1955 by Sir Robert Robinson, increased the available floor area by some 10,000 sq.ft. and provided valuable space for the erection of large pilot plants, thereby satisfying a need that had been growing for some years previously.

The conversion of these stables was expertly done, and there was little left to reveal to the uninformed the earlier role of the building. But there were two official links with the past in the retention of the name "Hayloft" for the small second floor that surmounted the buildings, and the preservation of a notice on the gallery of the pilot plant area which instructed staff to lead horses slowly up the ramp. Occasionally, unofficial links with the past intruded such as the time when an elderly gentleman, who was found deep in thought in the laboratory, observed that the space between two benches was the area where "old Betsy" used to be stabled. And the occasional plague of large bluebottles during a hot spell was said to be a legacy of the building's earlier function. A further link with days gone by took the form of Ben Thomas who, although eventually becoming a computer operative, started his working life as a stable lad at Fulham, and had many a tale to tell of the life style of earlier days.

1.6 The Fifties

In 1957 the scientific staff had increased to 70. The laboratories were still at that time wholly administered by the North Thames Gas Board. Indeed, staff were effectively North Thames Gas employees and the work was segregated into two categories: that undertaken for North Thames; and that undertaken as part of the Gas Council programme. The latter function was first acquired in 1951 and bestowed upon the laboratories the title London Research Station although initially this was a term that included Watson House. Dr Hollings had retired in 1952, although he maintained an association with the industry for many years as a Consultant with Woodall Duckhams. His place as Controller of Research had been taken by Dr Griffith who was based permanently at the Station, in contrast to Dr Hollings whose principal office was in Kensington and who, particularly in the post-war years, was not frequently seen in the laboratories.

Working Conditions

Judged by later standards discipline was strict, and staff were expected to conform to certain standards of attendance and appearance that were rigorously enforced. All staff below Senior Officer level had to sign in, and put their time of arrival in an attendance book which was on a desk in the laboratory. At the appointed hour of 9 o'clock Miss Budd or Jean Morris, who collectively constituted the general office and typing pool at that time, would draw a line in the book, and one's signature below that line indicated that one was late. In practice, if you arrived before Miss Budd you were early whereas if you arrived after Miss Budd you were late. And woe betide anyone who dared to sign 9.01 before the line had been drawn.

Miss Budd is remembered as one of the characters of that time. She was the focus of much of the administrative business and of the comings and goings of the Station, all of which she recorded on her blotter, which was changed only when every smallest area of space had been used up. It was said by some, not without an element of truth, that Miss Budd's blotter was the most important document in the Station. Miss Budd had the most unfortunate habit, from which she was never cured, of balancing files on her waste paper basket with the result that on several occasions frantic searches had to be made to retrieve some vital documents from the Station's rubbish bins.

Excessive lateness resulted in a reprimand from the Senior Research Chemist who could, if improvement did not result, arrange for the loss of Saturday leave. In the 1940s staff had one Saturday off per month, a concession that was extended to alternate Saturdays by the 1950s. Lateness by the manual staff was dealt with even more severely and twelve latenesses in a year resulted in the forfeiture of one week's holiday. So rigorously was this applied in the 1940s that when Prattley was called up in mid-year into the Navy the eight latenesses he had registered were adjudged to represent a lateness rate in excess of 12 per year, and he lost holiday entitlement accordingly. Saturday mornings at the Station were more relaxed than the rest of the week. Many staff used these mornings for jobs of a tidying-up nature, such as performing calculations from the week's results, writing up log books, or cleaning benches and equipment. Informal wear such as flannels and sports coats were permitted, but only with collar and tie. Work finished officially at 12.30 pm but in practice the general exodus would begin as soon as the Director had left. On one Saturday the Director set off at about 11.30 but just beyond the gate realised that he had forgotten something and made a sharp about-turn. The chaos that ensued as the larger part of the staff of the Station similarly reversed direction and scrambled back to their benches was remembered for long after.

All male staff were expected to wear brown laboratory coats of which they received an issue of two per year. Female staff were permitted to wear white coats (green for clerical staff) and later these were changed to pale blue. Slacks were frowned upon and were not regarded as acceptable wear until the late sixties. Female staff were first introduced into the laboratories during the war. The first to arrive were Miss F Rosa, Miss P Legge, Miss B Legge, Miss R Lindars and Miss E Mintern. By 1957 their number had increased to 16 including 4 graduates.

The men were expected to wear collar and tie and generally to dress formally. As one senior member of staff was heard to observe scornfully, "If you wish to be treated like a graduate you should dress as a graduate."

Wally Scudder goes on record as the first male member of staff to be allowed to wear no tie without reprimand. Scudder was a remarkable character who tackled every job with frightening strength and vigour, and on a massive scale. It came as no surprise to anyone when he dropped a glass carboy of strong acid on to the floor of No. 1 Laboratory, for he was accident prone. He must rank as being one of the few people who have been refused insurance cover for a bicycle, and must surely be the only cyclist on record who managed to collide with two milk floats at one and the same time.

During the 1950s as more space came available, Group Leaders were allocated a desk in an office which often was shared between two. Graduates each had a desk at their workspace, but desks for assistants were few and far between. There were very few telephones, at one time only one per laboratory, and private phone calls were discouraged. Smoking in the laboratories was frowned upon, although as time progressed this constraint was relaxed. Coffee was provided in the mornings by way of various coffee clubs, but staff were expected to consume their refreshment at their place of work. Tea in the afternoon was free from a trolley, and was accompanied by biscuits and sometimes cakes.

The mainstay of the messenger service was George Kingsbury, whose duties helped him in his role of principal stem of the grape vine. Few things happened at the Station that went unnoticed by him. For instance, on one occasion Graham went to Gas Council HQ to be interviewed for a job that was vacant there. Several weeks went by without any news of the outcome, until George stopped him one day on the stairs to tell him that someone else had got the job. This was the only indication that the applicant ever received, formally or informally, that he had not been selected. It was said by some that when Kingsbury retired it was necessary to create an Information Section at the Station although this is an assertion that was hotly denied. Kingsbury used to help out in the stores which were under the control of Joe Marsh. Joe was a popular character, with a splendid baritone voice, whose untimely and felonious death much saddened his colleagues.

Much of the apparatus used in the laboratories was home made and custom built for the job. Meccano was very much in evidence, and such items as pH controllers, magnetic stirrers, and constant feed devices were assembled in preference to equipment available commercially. For many years there was an informal training scheme in operation whereby new recruits would be given instruction in such basic crafts as glass blowing, the wiring of electric furnaces, and the use of asbestos for insulation purposes. The social life of the Station was very active in the late fifties, and three major evening dance/social functions were held within the space of 18 months, each attended by a large proportion of the laboratory staff and their spouses and friends. The first of these, held at the Star and Garter Hotel in Putney (at which a group of the staff gave a demonstration of country dancing that they were happy to forget), is remembered for an event that took place after the company had dispersed. On his way home one of the fitters was apprehended by the police for being under the influence of drink and taken to the police station where he spent the night. Moments before his arrest he had bidden farewell to his companion, a very senior member of staff, who was in a similar condition and who, thereby, had avoided the same fate by the skin of his teeth.

On 1st June 1957 there took place a unique event in the form of a family open day. On the morning of that day, a Saturday, the laboratories were thrown open to the relatives and friends of all members of staff, who were allowed to wander around more or less at will. The event was very well attended, and adjudged to have been a great success, but for some reason it was not repeated for many years.

Safety

There was no Safety Committee then and many practices were employed that would not have been allowed in later years. For instance, manual pipetting devices were not introduced until the late fifties and before that time all kinds of liquids were pipetted by mouth, including solutions of chemicals such as alpha-naphthylamine and benzidene hydrochloride, which later were prohibited from laboratories, and solvents such as carbon tetrachloride and benzene. Asbestos was widely used in string, fibre, and board forms, for insulation purposes, and large quantities of mercury were purchased and dispersed around the laboratories. At one time in No. 1 Laboratory rubber floor tiles started to lift at their centres caused, so it was assumed, by air bubbles. Investigation revealed that some of them were almost floating on pools of mercury.

Much could be written relating past practices that would make the modern safety scientist turn pale. Of Densham evaporating an inflammable solvent in a large glass apparatus, holding a bunsen burner in one hand and a CO_2 fire extinguisher in the other, each being used in turn, and on another occasion sucking up hot chromic acid in a pipette. Of Maccormac being lowered by bosuns chair into the (cold) slag bath to inspect the interior; of Joe Marsh carrying full-sized compressed gas cylinders upstairs on his shoulder; and of Jim Pentland burning up a hacksaw as he cut through a live power cable which he had been assured was safe.

Fortunately, despite such practices the safety record in terms of injuries sustained was remarkably good, but there were at least three near-misses where tragedy was narrowly averted.

The first occurred when Wylde broke his neck by falling to the bottom of a vertical retort during the course of inspecting the brickwork. Thanks to some fine first aid work on the spot, and to some expert hospital treatment, he eventually recovered and returned to lead the Refractories Group and reach a normal retirement. The second incident involved Jackman who, while carrying out effluent treatment work at Slough sewage works, inadvertently set out to walk across a ground level tank that was filled to the brim with thick black sewage sludge. To the horror of some bystanders he plunged into the foul liquid and disappeared completely from view. Fortunately, he was wearing a mackintosh which trapped some air so that after a few agonising moments he reappeared as a black hulk at the surface and was hauled to safety and quick recovery.

The third incident involved Ivens who was taking samples on his own at the Westfield Slagging Gasifier Plant. Unknown to him a leak of crude gas had occurred nearby which overcame him and caused him to collapse. Fortunately he was quickly missed, searched for and found, and removed to safety. But without this prompt action he might well have succumbed to carbon monoxide poisoning. Interestingly, this incident occurred in 1976 at a time when the Station had increased its effort on safety precautions.

The Research Programme

It is interesting to recall how in the fifties the work of the laboratories was initiated and monitored. Although there were constant adjustments and changes being made to the course of the work, the main structure and direction of the programme was laid down at a series of yearly meetings between the Director, the Senior Research Chemist, and the senior staff of each Group in turn. At these meetings each project was discussed in detail and decisions were taken about the amount and type of effort that would be devoted to it in the forthcoming year. Most Groups held regular formal meetings throughout the year, often attended by the Senior Research Chemist, at which progress would be reviewed and the tactics for progressing the projects would be decided.

Guidance was given by the Research Committee which included distinguished academics who met periodically to review the general direction of the research programme.

1.7 The Sixties - A Decade of Change

In August 1960 Dr Griffith retired thereby bringing to an end a distinguished scientific career. He was succeeded by Mr G U Hopton who, together with his successor, Dr J A Gray, were to guide the laboratory through a decade of development and changes that were to alter its character completely. These were to be the years of great transition in the gas industry during which it was to be changed almost beyond recognition by two technological revolutions into the natural gas supply industry that we know today. Not surprisingly these developments were mirrored by changes in the LRS that were to transform it from a research establishment that still preserved the character and style of the Gas Light and Coke Company to the Station which, up to its closure in 1993, played its role in the everyday business of the modern gas industry.

From North Thames to Gas Council

A significant feature of the research programme in 1960 was that only 8% of the effort of the 86 research staff of the Station was rechargeable to North Thames Gas which still owned the Station and administered it completely. The rest was charged to the Gas Council which was then effectively the governing body of the Station.

Recognition of this situation was made in 1961 when the Station was formally divorced from the North Thames Gas Board whose influence thereafter was confined to an administrative role which it performed for twenty more years or so on behalf of the Gas Council, and later British Gas. To meet its scientific and technical needs North Thames Gas established a central laboratory at Townmead Road which took over the coordinating role with respect to the works laboratories. This laboratory was staffed by selected members of the Paint and Corrosion, Refractories, and Gas Manufacturing Groups of LRS, and it was with some sadness that the Station thus witnessed the departure of many old colleagues including Lewis, Chilver, Williams, Hymas, Loveday, Highley, Gosling, and Mary Seaton.

Basic Research Group

A further development in this period was the appointment in February 1962 of John Gray, previously of ICI and the Battelle Institute, to form and head the new Basic Research Group. This Group was charged with carrying out fundamental research that would have long-term implications for the Industry's future. Although it was a separate entity it was housed in the Station's premises, initially occupying part of the top floor of the 1955 building.

Parkyns and Chapman were quickly absorbed into the Group and a recruiting campaign brought in a nucleus of staff that included Melvin, Patterson, Archer, Daglish, Shephard, Dongworth, Kitchener, and Mrs Goulding who acted as secretary. By 1964 the staff had increased to 18, and a programme of work was in hand in catalysis and kinetics, and mechanisms of high-pressure reactions, including the reaction between methane and oxygen and the hydrogenation of hydrocarbons. An expansion of the work to include flame properties and heat transfer was to follow shortly.

At first the group was viewed with a certain amount of suspicion, and even jealousy, by the rest of the Station. Even Dr Gray's appointment was viewed with a certain amount of good-humoured banter, and a quite senior member of staff wrote a poem which began, somewhat prophetically with the couplet:

"Dr Gray is here to stay, He's going to get a lot of pay..."

A certain free and easy attitude and disregard to convention was soon in evidence. Time-keeping appeared to be less rigorously enforced, although in fact most of the staff put in much longer hours than were apparent to the casual observer. First names were used freely, in contrast to the formal use of surnames which had been traditional at the Station. The staff wore white laboratory coats and seemed to have little difficulty in acquiring sophisticated pieces of equipment, the purchase of which, hitherto, would have required much justification. An active social life was pursued, and it was not unknown for the Group to disappear for a "working" lunch in Hyde Park, or to find some cause for celebration in the local pub. It is said that one Christmas a very senior member of the Group was asked to leave a pub by the proprietor who declared that "we don't want your sort here." Apparently the publican did not appreciate the said member's attempt to use scientific method, and some beer bottles, to reach as far as possible across the floor of the pub without touching it.

But this somewhat frivolous account should not detract from the splendid scientific achievements of this Group, which are recorded in Part 2 of this narrative and elsewhere.

Later, as ideas about the reorganisation of R & D within the Industry changed, the Basic Research Group was to lose its autonomy and become the Physics Division of LRS. Its contribution to the Station included a fresh approach to industrial research that was to have a considerable influence on the lifestyle of LRS in the seventies and beyond.

Engineering Research Group

Another significant appointment was that of John van der Post in 1964, who was brought in to form the Engineering Research Group. This Group was set up to study a range of metallurgical problems that the Industry was encountering, and to develop expertise in high-pressure pipeline technology and leakage problems in distribution systems. Accommodation for this Group's activities soon proved to be inadequate, and it made a temporary move to the old Watson House premises in Townmead Road. It is now just a formality to record that, unlike the Basic Research Group, the Group was not to be absorbed by the Station when John Gray was made its Director in 1966, but was to remove en bloc to Newcastle where it formed the nucleus that was to grow under John van der Post's leadership into the now, highly respected, Engineering Research Station.

Development in Michael Road

Other developments were in hand that were to have an important effect on the future shape and size of the Station. Under the watchful eye of Barry Newling, plans were being drawn up for extensive new laboratories that were to be built on the site of a row of old houses in Michael Road. The architects for the new building were the firm of Mayorcas and Guest, with W C French of Buckhurst Hill acting as the main contractor. First ideas visualised the extension as a corner building with a tall central section of five storeys, flanked by a four storey wing on one side and a three storey block on the other. This idea was rejected in favour of the existing design which was proceeded with in two phases that were completed in 1966 and 1967.

In February 1966 plans were drawn up for a third phase of development consisting of a heavy store on the site in the yard that was later occupied by the 1976 building, and a multi-storey car park to accommodate 150 cars on the site of the car park in Michael Road. An Industrial Development Certificate and planning consent for this phase (which was costed at £100,000) were obtained, but in the event sanction for the development was not given, chiefly due to the lack of capital resources. Plans for Phase 3 were finally abandoned in 1971 when preparations for the construction of a core store on the works began, and when it seemed that there might be a need for a different building on the yard site to house a proposed combined heat and power scheme for the Station, which in the event did not mature.

When it became clear during the construction of the new building that the development of an engineering research function for the industry would take place elsewhere, and that the large central well in Phase 1 would not be needed for pilot plant work, an estimate was obtained for bridging over the void on three floors to give 6,400 sq. ft. of new floor space. The estimate, which came to £61,600, was considered to be too high and the project was dropped. This possible development was resurrected several times later, each time to meet the same fate, and its elusive attractions continued to haunt the Station management until it was known that research at LRS was scheduled to come to an end.

It is interesting to recall that in 1966 Phase 3 was regarded by the management as the final phase of development of LRS which would then be sufficient to accommodate a total of 300 staff. In the words of the draft proposal:

"This is regarded as the largest number that can be effectively controlled by a single research administration.. ..."

The new building, which came to be known as the 1966 building, was formally inaugurated by Sir Henry Jones on 2nd July 1968, and won a Civic Trust Award. This was bestowed in recognition of its external appearance which was considered to enhance the neighbourhood. It is said by some that the ramshackle and derelict nature of the environs of the Station at that time detracted from the honour of this award. Others of a more irreverent nature likened the white-tiled facade to that of a public convenience. Admittedly certain minor faults, such as the fact that the passenger lift cut out when the sun shone, were soon rectified once cause and effect had been established, but a major deficiency in the form of a heating system which appeared to be controllable only to two temperatures - too hot and too cold - remained until the end. And the interior partitioning, which was installed with the admirable idea of being adjustable to meet changing requirements, proved to be less amenable to change than was intended and transparent to sound to an irritating degree.

But it is unrealistic to expect that any research laboratory would please everybody, and most of its occupants agreed that the building provided very acceptable accommodation in meeting the requirements of research work in a range of topics with extremes as diverse as computing studies and microbiology. Most of the jokes about the Station's exterior were forgotten, and even some of the early detractors were prepared to admit later that maybe those trustees of the Civic Trust Award had the right idea after all. With the occupation of the completed buildings the old 1927 building was vacated and the bricks and mortar link with the old Gas Light and Coke Company laboratory was finally broken.

1.8 A Wider Role

The separation of the laboratory from the operating functions of the North Thames Gas Board left it without the facility of easy access to operational sites and plant. The Station had to get used to the idea that it now had the sole function of serving the industry as a whole and that new contacts had to be made and established with all Area Boards and departments. This process went on in numerous ways, but it is possible to identify certain areas where particular progress was made in establishing the foundations of a corporate role for the laboratory.

Yearly meetings of scientific and technical staff from the Area Boards were set up (the first of these in 1963 on chromatography was probably the first time that Area Board chemists had formally been brought together) to review advances and coordinate progress in specific analytical techniques. These meetings can be regarded as the forerunners of the annual Scientific Services meetings that continued in several forms for many years. This was just one of a series of initiatives, in which Bill Armstrong and Gerry Boreham were prominently involved, that were undertaken to establish contacts with the scientific departments of the Area Boards. Later, the Scientific Services Panel was set up (known initially as the Working Party on Analytical Methods) which comprised representatives of the Research Stations and the Scientific Services Managers from all of the 12 Regions. From 1975 to 1988 this Panel was chaired by the Director of LRS.

In the sixties mobile teams of plant operators were organised to assist in the commissioning of new gas making plants. Assistance was given with the commissioning of the Canvey-Leeds methane pipeline, which was to lead to work on dewpoints and natural gas properties. Studies were instituted of the odorisation of reformed gas, and later the selection was made of an odorant that was suitable for addition to natural gas produced from all sources. A major study was initiated of the internal sealing and gas conditioning of mains to control leakage in distribution systems. All these activities took staff out into the field, often to remote places, not least of which were the offshore drilling rigs prospecting for gas in the North Sea. Here staff attended production tests at the wellhead to obtain early information on gas composition and properties.

A visit to a drilling rig, usually by helicopter, sounds like an exciting event, and certainly the first visit or two for any member of staff was full of interest. But the trip could be a tedious affair with much waiting around on-shore and on the rigs at the mercy of the whims of the weather and the operators. On one occasion DeRose was deposited on a rig only to find that no arrangements had been made to take him off. On another occasion Beale watched with horror as a helicopter dropped his equipment into the sea. Another member of staff had an anxious moment when part of the tail rotor of his helicopter was knocked off by a bird. Access to and from a rig by boat was no less exciting and several staff suffered the hair-raising experience of being winched aboard the rig from a bouncing boat while clinging to the outside of a basket. But nobody fell into the water, although Baldwin did descend 380 feet in a diving bell to get samples of water at various depths, and had one moment of anxiety when the bell banged heavily on the sea bed.

It would be an omission not to mention the name of Bramley Densham who for some years was responsible for organising many of the field activities referred to here, and who played an active part in many of them. Bram was never short of ideas and had an aptitude for improvisation. For instance, while engaged on work on the detection of nickel carbonyl in gas at Westfield a problem of communications arose between staff situated at each end of a long gas sampling line. Bram suggested that semaphore should be used and, in the event, two messages were sent by such means both, regrettably, unprintable. On another somewhat historical occasion, at the end of the initial purging operation on the No. 1 Feeder main from Easington Terminal, Bram filled a small cylinder with gas, then lit the gas from the cylinder with a match, and proceeded to light a cigarette from the gas flame. With a sense of occasion he declared the act to be the first practical application of North Sea Gas.

Another legendary character who could be mentioned here is Dr Maccormac. He organised the teams that assisted in the commissioning of new gasification plants, although such was the variety of projects he initiated over the Station's history that it would be opportune to mention him at almost any point in this narrative. Maccormac is remembered for his inventiveness resulting in a stream of ideas which he pursued vigorously despite the handicap of a disablement inflicted by polio while he was in his prime. His work on a series of pilot plant processes, particularly that which led to the establishment of peak load plants at Southend and Southall, culminated in the early sixties with development work on the double-shaft slag bath gasifier, situated at Bromley. Ultimately, in common with much post-war work on gas manufacture, the project was shelved, in this instance before the plant had reached its design performance. But a film of the work was made, and numerous stories survived, mostly in the form of accounts of fires and explosions that punctuated the progress of this project.

Examples of his inventiveness can be found in the account of the investigation he pursued on his own initiative in the late sixties of the causes of a well-publicised explosion in a block of flats. Dr Mac., with characteristic thoroughness, initiated all kinds of ancillary investigations ranging from a study of the distillation products of gramophone records to the calculation of the explosive potential of a much ill-used mattress. Eventually, in a disused air-raid shelter on Beckton Works, he succeeded in blowing up a mock-up of a kitchen by igniting the propellant from starch aerosols of a type found in the wrecked flat. But it was to no avail for by this time the authorities had reached other conclusions. In later years it became fashionable to enquire, "How can we encourage creativity in the Station: are there sufficient good project ideas coming forward?" It is unlikely that the questions were heard in Maccormac's day.

The month of June 1966 can be seen in retrospect as being one of some significance for the Station. Dr Gray became its fourth Director, while Mr Hopton was appointed Co-ordinator of Research at the Gas Council. This was a new post and marked the beginning of what was to develop into the R & D HQ function. That month also saw the founding of the Systems Engineering Group at the Station under the initial leadership of Bob High and later of Walter Bellars. The Station had already installed an Elliot Arch 1000 computer for the purpose of controlling the pressure pilot plant for removal of carbon dioxide from gas, and it was to this subject of the control of process plant that the Group first turned its attention. In October an IBM 1130 computer was commissioned in the new building, and by this time the Group had expanded its interests to include assistance in the design of the embryo high pressure methane grid. The development of this work in the form of network analysis of transmission and distribution systems provided the impetus for the gradual growth of the Group ultimately into the Maths and Computing Division that formed a major function of the Station. The original IBM 1130 soon became inadequate and was moved to a new location and expanded in November 1968. Eventually it was replaced in April 1973 by a Univac 1106 which had the additional function of acting as a standby to a similar computer that was used for the control of the national grid at Hinckley.

The development of the Maths and Computing function introduced yet another new element into the Station. Strange reclusive characters appeared who spoke an incomprehensible jargon, with expressions like 'real-time' and 'adaptive modelling', and worked on mysteriously named projects such as SATAN which was reputed to have a fast execution time, and SNAC which apparently superseded DEVIL. But gradually the ice cracked, and then broke, as the rest of the Station began to realise that these activities, and the characters engaged on them, were not so mysterious after all and could be quite useful in all sorts of applications. And as for the jargon - well it had to be admitted that to the mathematician expressions such as 'pH', 'X-ray fluorescence', 'field ionisation', and 'nickel-urania-alumina catalyst' were just as incomprehensible.

June 1966 also marked the appointment of Tommy Noble as Head of Information Services, with the brief of expanding the library into an information unit to meet the growing needs of the Station in this field. Among Tommy's many attributes was a unique command of English and, using the authority of his new position, he proceeded to impose strict standards on the written output of the Station. All, from the Director downwards, were exposed to his uninhibited but constructive criticism of their literary efforts. For instance, Peter Graham once proudly submitted the draft of a lengthy report on which he had spent many painstaking hours, and was dismayed to receive it back annotated with about 200 comments from Tommy, and headed by a quotation from Montaigne that read:

"No one is exempt from talking nonsense; the misfortune is to do it solemnly."

Tommy was a controversial figure who trod on many toes during his career. But few failed to appreciate his sense of fun which frequently bubbled to the surface, as for instance on one occasion when his Group Leader, Michael Badger, returned from holiday, Tommy chose to give a report of the Group's activities in the form of 98 lines of verse commencing:

"Welcome back most mighty Lord, From thy sojourning abroad. You've been in the Isles of Scilly, We've been working, willy-nilly, Working for your greater glory, So we could relate this story ..."

and ending: "Shine above us, mighty, glorious, While below we work laboriously, as fitteth lesser spirits, Conscious of inferior merits."

Such was Tommy's influence that for many years after his retirement long-serving members of staff could be heard to appraise reports and suchlike with the comment: "Tommy Noble would never have approved of that."

1.9 The Seventies

In the Autumn of 1970 the managerial structure of the Station was modified by the reorganisation of scientific staff into three Divisions concerned with Chemistry, Physics, and Maths and Computing. Two of these Divisions were based on Groups that had been formed during the previous eight years. In September 1971 John Gray succeeded Mr K L Stretch as Director of Research of the Gas Council's R & D Division. For the next six months Geoff James, a senior Assistant Director, controlled the affairs of the Station until on the 1st April 1972 Mr T A Dick, formerly Area Chief Chemist of the West Midlands Gas Board, was appointed its Director. The appointment represented something of an innovation since it was the first and (as it was to transpire) only time that an 'outsider' had been brought in to conduct its affairs. Not that Terry Dick was a stranger to the Station. Indeed for many years he had been a frequent visitor to LRS and had established friendly contacts with many of the staff. In his capacity of Area Chief Chemist of the West Midlands Gas Board he had done much to pioneer working contacts between the Area Boards and the research function, a policy which he continued to implement during his short tenure of the post of Director.

Reorganisation

A further reorganisation took place in 1973 with the splitting of the rather massive Chemistry Division into the Analytical and Operations Divisions, and with the organisation of the administrative and services functions of the Station into two additional units. Seven years later the two services units were combined into a Services Division and thus the divisional structure of the Station was finalised.

Other developments were in hand that were to alter drastically the way the Station selected and evaluated its projects. In 1968 project sheets were introduced for the first time, and mathematical techniques were used with the aim of selecting projects that were likely to produce the greatest economic benefit. This exercise had only limited success, but stimulated ideas along these lines until in January 1972 a project planning and control system was introduced based on recommendations in a report by the consultants McKinsey and Co. Inc. who had been brought in to advise on the Industry's planning and control of R & D. This marked the beginning of the system that developed progressively into the management and planning procedures which set out to align the R & D programme with the Industry's objectives and time-scales. Later on occupation sheets were introduced on which all staff were required to account for each tenth of every working day by allocating it to a project or some overhead activity. Thus was introduced a system of project budgeting and accountability that was undreamt of in earlier days.

It was during this period that demands for more working space became acute. The situation was eased slightly by the departure of Watson House staff from the void and the western ends of the first and second floors of the 1966 Building - areas they had occupied since 1967. But some of this space was rapidly gobbled up by a new computer and, with the prospect of the return of part of the Analytical Division from temporary accommodation in the Fulham Works Laboratory, the demand for more working space continued. This was met by the erection of a prefabricated two-storey building, known as the 1976 Building (but less officially to be known with some affection as the cardboard building) at a cost of £50,000, in the yard space previously used as a car park. Its initial function was to house the Information Division and Library on the ground floor and the Engineering Services Group and a lecture theatre/conference facility on the upper floor. This released valuable space in the main building for conversion to laboratories. Another modification to the site during this period was the installation of a stand-by generator to meet the basic electrical requirements of the Station in the event of the failure of the LEB supply.

Newsletters

Two newsletters produced by the staff made their appearance during the period 1973-75. The first entitled "Gasbag", produced by the energetic team of Susan Baillie, Rogan Boon, Heather Nicolle, and Dennis Weeks, set out (with a nod of approval from the management) to give news and views about life in LRS, and rapidly established a reputation for itself both within and outside the Station. The second, which achieved a somewhat different reputation, was an anonymous publication called "Salt Cavern" that commented in humorous but usually uncomplimentary terms on certain management personalities and decisions. The publications were short-lived and were possibly in their own ways both expressions of the same phenomenon: the disappearance of the parochial or family atmosphere of the early days, a change that had been taking place during the previous decade or so as the result of the diversification and expansion of the Station.

The Corporate Role

The departure of Terry Dick was accompanied by other comings and goings in the Directorate of the Station. Geoff James once again controlled its activities for some months on a temporary basis until Graham Cribb (who had originally joined the Fulham Laboratory in 1949) returned in 1975 as its new Director after some 15 years in the Production and Supply Division. Meanwhile, Barry Newling and Bill Armstrong both chose to retire after long and distinguished service, and shortly afterwards Walter Bellars was appointed Assistant Director.

It can be said that in some ways the early seventies were uneasy years for the Station. The old association with North Thames Gas, which had continued by personal contact after the formal transfer of the laboratory to the Gas Council, had greatly diminished, and with the formation of the British Gas Corporation in 1973 the administrative links with the Region were progressively weakened. Furthermore, unlike the other Research Stations, the LRS was not clearly aligned with any particular operational function of the Industry, but performed a somewhat ill-defined role by way of providing a variety of specialist services in a wide range of topics, seasoned with a mixture of fundamental research and diverse trouble shooting activities. Not surprisingly those with cynical tendencies could find opportunity to interpret the Station's function as being that of an elite "Jack-of-all-trades" pulled first in one direction and then in another according to the whims and fancies of Headquarters and Operational Divisions.

Graham Cribb identified the diverse capabilities and functions of the Station as representing a virtue rather than a disadvantage, and set about to establish the Station as the Corporate Laboratory of British Gas, as outlined in his Research Paper on the subject.

"There is no doubt in my mind that LRS has a definite role to play and, although this role may be more difficult to define than that of the other Stations, it is no less important. It is questionable whether British Gas needs four Research Stations, each aligned with specific sections of the programme... On the other hand with three Stations so aligned and the fourth (LRS) covering a broad front, but in limited depth, the flexibility of the R & D Division to match resources with required effort is much greater."

The Golden Jubilee

The year 1978 was in many ways a significant one for LRS, for the 26th July marked the 50th Anniversary of the establishment of a chemical engineering laboratory on the Fulham gas works site. Graham Cribb decided that this event would be celebrated in some style. The doors of LRS were flung open on three consecutive days during which invited visitors from the gas industry, from outside firms and organisations, and from the families of the staff, were welcomed, entertained, and guided around or let loose in the laboratories.

Many and long were the preparations for this occasion. Repair and redecoration of the buildings were scheduled for completion just before the event. All kinds of visual aids were commissioned by way of wall boards and display panels, and of slides and films to illustrate the various aspects of the Station's work and history. A competition was organised amongst the staff to select a logo for the occasion, and this was used on the copious literature that was published, and on the commemorative mugs and glassware produced as souvenirs for staff and visitors. A massive marquee was erected in the car park to deal with the hundreds of meals issued free to visitors, and a large area of the works was set aside to receive the numerous cars that poured through the gate.

Although much use was made of the occasion to up-grade the material and literature required to demonstrate and explain the Station's current work, the time was primarily one for looking back, and as part of the exercise a booklet was produced (which has provided much of the source material for Part 1 of this history) that traced in a fairly light-hearted manner the fortunes of the Station and its staff during the previous fifty years.

The booklet devoted scarcely a page to the future, confining itself in this respect to speculation about the development of buildings and accommodation and, by way of a frivolous cartoon, to the idea that there might one day be a centenary to celebrate at LRS. Perhaps the authors can be excused for failing to foresee that within ten years the death knell of LRS would have been sounded, and that a gradual run-down of the Station in preparation for 'better' things would be in hand.

But there was no thought or idea of this as the Station prepared for the eighties, for there were already hints of further developments of the site, and of further expansion of the scope of the work. The idea of a Phase 3 extension to the 1967 building had been resurrected in the form of tentative plans for a building on the site of the Michael Road car park to house a new computer complex. Negotiations were in hand to acquire a large area of the former Fulham Works to extend the Station's capabilities of carrying out large scale pilot plant work, and an extension to the core store was mooted. A new front entrance was being considered, and the Station had accepted responsibility for the security of the 'works' gate. As we shall see, all these plans were to mature in some form at least, although the concept that the original 1927 building would in some way be restored to its original function was not to materialise - much to the relief of the Engineering Services Group.

1.10 Site Development in the Eighties

The four or five years following the Jubilee saw a flurry of activity to develop the site facilities. Much of this was due to the efforts of Maurice Tanner, Assistant Director in charge of Administration, ably assisted by Alan Daglish, Manager of Services Division.

The first major development of site facilities in this phase was the conversion of the "Fitters Block" on the Fulham site to laboratories to house the heavy work of the Operations and Physics Divisions. This was subsequently dubbed "The '78 Building", referring to 1978 its date of conversion, although 1878 would not have been far removed from its date of construction.

In March 1979 plans were in hand for a new computer building to be situated on a site close to the old dock on Fulham Works. This did not mark an extension of LRS, however, but the establishment of a new department - subsequently known as London Computing Centre - which was to be responsible for the main computing functions of British Gas Headquarters, other than those within R & D Division, and those associated with Central Control. Eventually, LRS was to see the departure of its main frame computer to this building, together with some of its associated computing staff.

By October 1979 a horseshoe-shaped area was being cleared around the central pressure reduction station and holder site on Fulham Works for LRS use, and by November 1980 a new concrete roadway to serve this area had been laid, and the construction of a new core store had commenced. Later, the old core store was converted to house leakage control work, following the transfer to LRS of the Engineering Research Station's effort in this area.

Further development of this new area continued in April 1982 when construction began of the Test Rig Facility, a building designed specifically to house test rigs and pilot plants that required stringent safety precautions.

In the meantime, development of a 'temporary' nature had taken place in the form of the provision in May 1979 of two large Portakabins in the yard adjacent to the 1966 building to provide laboratory and experimental 'greenhouse' facilities for the Biological Sciences Group. Later, in 1982, this Group was to occupy Redloh House, which had been restored and refurbished by LRS Engineering Services from near dereliction to a compact and pleasant laboratory facility, with offices on the first floor. Later still the Group was to expand further into part of the adjacent surgery block which, likewise, had been expertly refurbished.

The final, and perhaps major development of the site, namely the construction of an Analytical Building, did not progress beyond the stage of preliminary design, despite the fact that the justification for this building was probably better prepared and argued than any other post-Jubilee development on the LRS site.

In April 1982 external consultants were engaged by LRS to advise on all aspects of future development of the Station. A major incentive for this study was the realisation by LRS management that, despite the steady expansion, laboratory space was inadequate, that the allocation of workspace could be improved, and that expenditure was needed to enable much of the older accommodation to meet current and impending safety regulations. These deficiencies were to be found in the 1966 Building itself.

Central to the many recommendations of the consultants was the provision of a new building to house the Analytical Division. But as the plans for the building progressed, and paperwork drafted for financial approval of the scheme, so the winds of even greater change had begun to stir. And by March 1987, when talk of the "rationalisation of R & D" was first officially heard at LRS, the proposed Analytical Building was already a dead duck.

Other site developments and improvements that came to fruition throughout the eighties included: a major refurbishment of the restaurant and kitchens; the installation of a new telephone system in 1981; the provision of a new car park on the works and a walkway to it which was opened in 1983; the taking over by LRS of the old Platers Shop in 1984 to house part of the engineering services function; and the refurbishment of the Library and re-housing of the Print Room in 1986. And in November 1985 the void in the 1966 building was at last put to more systematic use by the erection of prefabricated partitioning on the ground floor, to provide office space for the Maths & Computing Division and light laboratory facilities for materials work.

Fires occurred in the first floor laboratories of the 55 building in 1980 and 1985, both of which required extensive reconstructions of the roof and interior. These were the only fires of any significance that occurred at LRS during its 66 years of existence, despite the fact that much of its work during this period was concerned with flames, combustion, flammable materials, and high temperature and pressure processes.

1.11 Working in LRS beyond the Sixties

It is probably true to say that during the period covered by the latter part of this narrative the working life of the staff changed beyond recognition compared to that of the earlier years. In the eighties, a typical member of staff on a typical working day would deposit his car in the car park and make his way to the front entrance of the 1966 Building where, unless he could capture the eye of the receptionist, he would enter his card key into the lock and select the number that would allow him entry. If required he would sign the book at the desk, although this practice was later abandoned, or if he was on Flextime proceed to his clock which he would actuate to start recording his working day. Facing him in the entrance he might see a notice board giving him the location of a meeting that was to be held that day, or revealing what the music club would be listening to in the lunch hour, or telling him that the nursing sister would be in attendance for consultation.

Alternatively, he might proceed directly to one of the other laboratory buildings on the Fulham site along the main works road that once bustled with the comings and goings of the workers and lorries serving a busy gasworks. In the eighties it was busy with activity of a different kind following the installation on the site in April 1978 of the Customer Service Department of the Central Division of North Thames.

Sometimes our typical member of staff would be required to travel away for part of the day to Holborn, Marble Arch, or Rivermill House, or perhaps for a longer period to another Research Station, or to do some field work. If he was anything but a very junior member of staff he would travel to his venue by First Class rail, or on car mileage or, after privatisation and if he were senior enough, in his Company car. But most of his days would be spent in a fairly routine way, performing a duty defined by his job description, and allocating his time in units of 1/10th of a day to a prescribed programme or overhead project code.

Gone were most of the pieces of glassware that once littered his bench and which contained his chemical reagents and reactions. Gone too were the assemblies of glass flasks bubbling over bunsen burners, condensers and bent tubes, sometimes wrapped in powdering asbestos string. In their place were an array of metal boxes of various shapes and colours, sporting flashing lights and digital readouts, and spewing recorder charts and computer listing paper. Work involving solvents or any substance that produced a smell was confined to one of the sixty or so powerful fume cupboards that did battle with the laboratory's air ventilation system. Regular medical checks on staff were made where appropriate, and a formal assessment was made of all potentially hazardous operations in accordance with the COSHH (Control of Substances Hazardous to Health) regulations.

Our typical member of staff would be called upon to attend an increasing number of meetings, to write reports according to a prescribed format, and to read a stream of documents including the minutes of the JCC and the Safety Committee. He would be required by law to work in a safe manner and not show discrimination to sex or race, and until 1985 would have been obliged by National agreement to belong to an approved trade union. Nobody expressed surprise if he appeared for work in casual clothes, and everyone from the Director downwards would have addressed him by his first name. In several ways his working regime was in direct contrast to his predecessors: he worked in a much more casual style to a much more formalised safety regime and programme of research.

Further changes to working life in the Station were introduced after privatisation in 1986. These included the introduction of a new salary structure, with progression depending much more on job performance than on length of service. In 1988 part of the funding of research was placed in the hands of the Industry's operational divisions ('Business Units'), and a considerable proportion of the LRS effort had to be commissioned from such sources. A beginning was made in 1989 to introduce matrix management more widely into the research stations, a system which for some years before the LRS management had explored but not implemented.

1.12 Growth and Decline

In terms of the number of scientific and technical staff, the Station reached its maximum size towards the end of 1986. The growth and decline in the numbers of such staff are shown in Fig. 42 which gives figures for various dates for which data were available.

In April 1987 the number of scientific and technical staff was 205, while the total number of employees at the Station (including 9 part time cleaners) was 301. Thus the estimate of 300 that the directorate of the mid-sixties had named as a desirable maximum for the Station had been reached - more by chance than design. The divisional structure of the Station at about this time, and its prominent members of staff, are shown in Fig. 43.

In the last 15 years or so in the life of LRS the Station had probably become more closely involved with the day-to-day national operations of the Industry than at any time in its history. The continued development and centralisation of a highly organised planning and control system governing the programme of R & D Division, (later re-named Research and Technology Division) and its increasing participation in the committee

structure of the Industry, gave the Station closer nationwide links with senior operational staff, and those from other research stations, than ever before.
But in other ways these were uneasy years for LRS, especially as it progressed through the eighties. The Station seemed to be under constant scrutiny from one efficiency study or another, and although these were not specific to LRS they gave rise to increasing speculation among the staff about its future. The future of R & D in the Industry was a frequent topic of conversation, and there was never a shortage of rumours about an impending closure of the Station, the removal of LRS to another site, or its amalgamation with another research station.

Staff became more defensive about their research projects, and reactive to the implementation in other research stations of work that was thought to be the province of LRS. As the eighties progressed the morale of the Station began to suffer under the burden of such rumours, and it came as no surprise in March 1987 when the official announcement was made that the Station was indeed to close and to be amalgamated with Watson House and the Midlands Research Station as soon as suitable accommodation had been secured. In the event the first choice of Stoneleigh in Warwickshire for the new station ran into planning difficulties, and the alternative site at Loughborough was found.

Six years was to elapse from the announcement of amalgamation plans to the closing of the Station, but from the day of the announcement a steady run-down of staff commenced. Major departures came with the removal of some of the maths and computing, and leakage control work to ERS in April 1989, but staff were leaving for other reasons such as early retirement, the reluctance of staff and their families to remove from London, and the uncertainty of others about their career prospects in the Loughborough station.

Eventually it was announced that the Station would close in June 1993, but in several ways LRS had lost its identity long before this. The job titles associated with the Station Directorate had gone by June 1992, and matrix management (referred to earlier and again in Part 2) which embraced the whole of R & T Division, had become well established.

December 1992 saw the first signs of impending redundancies - an innovation for the Station. The Business Units, referred to earlier, had not placed enough contracts with R & T to cover the wage bill for 1993, and some staff started the year without a project to which they could allocate their time. On 21st January 1993, as part of a Headquarters reorganisation, staff were invited to apply for voluntary redundancy and redeployment. Only after sufficient staff reductions had been achieved were further staff to be invited to apply to go to Loughborough.

The terms for voluntary redundancy were for many staff not unattractive, and a large proportion of the long-serving and senior staff accepted them rather than endure the domestic upheaval and, in some cases, career uncertainty associated with a move to Loughborough. Thus the closure of LRS saw the premature departure from the Company of senior staff such as Walter Bellars, Grev Gibson, Alec Melvin, Norman Parkyns, Richard Gibbons and Doug Douglas.

LRS staff accepting or finding posts at the new research station at Loughborough (Gas Research Centre) included Frank Shephard, Peter Tippen, Peter Dishart, Richard Mounce, David Smith, David Keene, Ken Platt, Fred Starr, Roger Newell, Brian Sleigh, Jim Curr, Zlata Heller, Neil Slater, and Adrian Robinson.

Those staff for whom other options were unattractive went on the Headquarters re-deployment register which enabled some of them to find suitable jobs elsewhere in British Gas.

By the beginning of February 1993, the gradual run-down of the Station was taking effect, and the number of scientific and technical staff had diminished to 171. In practice this is probably an inflated figure of the people on site, since by this time a number of staff, although still on the establishment of LRS, were working in other British Gas departments.

1.13 The End Approaches

In the last months at LRS very mixed emotions were in evidence. Those destined for Loughborough went mostly in good heart, looking forward to the new life that awaited them there. Those accepting voluntary redundancy did so with mixed feelings - reluctant to go, but relieved on the other hand to see an end to the uncertainty which had been a feature of their life and work during the previous few years. But many who were left at the closure with no firm idea of what the future held for them in British Gas were disgruntled with the way that LRS had been run-down in general, and the way they had been treated in particular. This is not the place to pass judgement on these opinions, but merely to record that they existed.

In January 1993, five months before LRS closed, a poignant event occurred that passed largely unnoticed by the younger staff of LRS. This was the death, at the splendid age of 100 years, of Harold Hollings who, from his retirement home on the North Yorkshire Moors, had watched with interest the development at Fulham of the research function that he had initiated and established.

On the 7th May 1993 a rather peculiar letter was received by those retired LRS personnel who were on the Headquarters list of pensioners. By unintentional omission it was not sent to the many ex-LRS personnel on the equivalent North Thames list. The letter invited the recipient to an "Open Day" to celebrate the closure of the Station. The letter was on notepaper from the Midlands Research Station, and the event was to be supervised by a senior member of the Watson House staff. The confusion was added to when it was found that far from being 'open' the work areas of the Station could be visited only under close supervision. This constraint was because LRS was in the early stages of dissection, and it was felt, not unreasonably, that there were too many hazards to allow unlimited freedom of movement to the visitors.

Those attending were given mementoes of an LRS T-shirt and a British Gas pen, and found a nice buffet awaiting them that gave them an opportunity to meet, perhaps for the last time, with past colleagues. But it was felt by some that the event lacked the sense of occasion that perhaps it deserved.

The official closure of LRS came on 30th June 1993, but here again there was no formal ceremony. An informal invitation had been issued to the staff who were left, and to ex-staff within reach of Michael Road, to a free buffet lunch. Rather more than a hundred attended.

The working areas and offices of the main building were in the early stages of dereliction. Benches stood empty except for a clutter of litter and bits and pieces of minor equipment that had been abandoned. A couple of major items, for instance the scanning electron microscope which needed special transport, had yet to be moved. Elsewhere contractors were already looting the place of salvageable items such as ventilation trunking and extraction fans. In offices, doors of empty cupboards hung open, and wastepaper bins stood full of junk.

Charles Tapper's laboratory - the 1927 Building where it had all begun at Fulham - stood quiet, ignored and aloof along the road. It had been used for some time by North Thames Gas as a store, so it was said. The impressive staircase which Sir Richard

Threlfall and his top-hatted party had mounted some 65 years before to perform the opening ceremony was unattended and covered with a layer of dust. The two bulbous supports of the balustrade that had been hastily turned out of wood by the Fulham carpenters, before the opening ceremony, as a temporary measure to replace two defective concrete ones, were still there, having weathered the passing years rather better than their concrete companions.

For many of those present on the 30th June this was their last day with British Gas. Some of them expressed uneasiness that such a big event in their lives was taking place with no one senior there to say goodbye and wish them luck. The most senior person there on the day didn't seem to count somehow, because it was his last day too. "It seems a bit of an anticlimax", said one, "after thirty years at LRS."

When the time came to leave, each picked up his bag or case of personal effects, shook hands with anyone he could find pottering about in a nearby desolate office, called out 'cheerio' to whoever he met on the stairs, and left through the front doors. Even the receptionist who glanced up at the departing figure was a temp.

And so research came to an end at Fulham. The London Research Station which opened as the No. 1 Laboratory of the Gas Light and Coke Company - one of the first chemical engineering research laboratories to be established by industry in the UK - would exist no more except in the minds and memories of those who had worked in it.

All things come to an end, and no one could expect that research at Fulham would go on for ever. Even the sparkling new Gas Research Centre at Loughborough with, hopefully, a bright future of achievement stretching before it will one day close its doors for good.

If the closure of LRS caused any surprise it is perhaps that the research centre lasted so long, having successfully adapted itself and contributed to the incredible changes in the gas industry that occurred during the transition from a declining Victorian industry to the modern enterprise that is British Gas, arguably one of the most successful businesses in the world today.

The Gas Research Centre started its life at Loughborough as a hybrid organisation, drawing staff and elements of its first programme from three research sites. As time goes by and it builds its own identity and tradition its links with its origins will become weaker and, as its staff moves on and changes, the past will become of diminishing consequence.

But hopefully, now and again, there will be occasion to remember, perhaps with the help of a narrative such as this, those pioneers, many fresh from University, all full of ideas and enthusiasm who, between the two world wars and the turbulent years that followed, found fertile ground at Fulham in which to sow some of the seeds of a new gas industry.

PART 2 THE WORK OF LONDON RESEARCH STATION

CONTENTS PAGE

2.1 Introduction

The history of the Station's work can be divided into two nearly equal periods. The first period of 30 years or so was concerned primarily with research into the production and purification of coal gas. Subsequently the Industry was then involved in two technological revolutions. Not only did the Station have to adapt to the phasing out of coal gas production but it had to absorb some organisational changes as well.

During the second period the London Research Station adopted a divisional structure and, in the 1970s, assumed the role of the Corporate Laboratory of British Gas. The research in this period is conveniently reviewed by considering the work and roles undertaken by the four technical divisions, and tracing how their ultimate capability developed.

PERIOD 1 - THE EARLY YEARS

2.2 The First Programme

The appointment of Harold Hollings in April 1924, and the establishment of a temporary research laboratory at Horseferry Road, were described in Part 1. In July of that year Sir David called for a verbal report on the research topics that should be included in the programme.

Hollings thought that little was to be gained by working on the horizontal retorts. Their productivity was good and their thermal yield only marginally below that obtained in the South Metropolitan Company. (This observation was enough to initiate a campaign by Sir David to improve the thermal yield of the Gas Light and Coke Company retorts). On the other hand far less was known about continuous vertical retorts and the problems were more complex and interesting because of the presence of a waste heat boiler.

There had been no carburetted water gas plants in the South Metropolitan Company so Hollings had to admit to Sir David and the Chief Engineer, Thomas Hardie, that he knew very little about the subject. He considered, however, that it was a fruitful area for study, since there was no specification for gas oil and no apparent relationship between its composition and thermal yield.

Thomas Hardie asked about oxide purifiers and Hollings agreed that this was an area where the scientific approach was entirely lacking. However, there was little point in studying oxide purifiers until the performance of the upstream plant had been improved. The cooling and dehumidification of gas in cooler-condensers had been the subject of scientific investigation by Carpenter, but the situation at that time with respect to ammonia recovery was chaotic. Harold Hartley, recalling his war experience, suggested that active carbon should be investigated as a clean-up agent for coal gas.

From these initial thoughts the programme developed in breadth and depth over the next 30 years and much of it is described in papers of the learned institutions. New problems arose, such as gum formation, and the more detailed story is best related by reference to the various stages of the manufacture, cooling, washing and purification of town gas. The term town gas is used rather than coal gas because low pressure cyclic oil gasification was not without its problems.

2.3 Gas Manufacture

Coal Carbonisation

Just before the official opening of the Fulham Laboratory, Hollings gave a paper to the

Institution of Gas Engineers in 1928 entitled "Some Applications of Chemistry in Gas-Making" (3). This described the initial investigations into carbonisation over the previous four years. A conclusion was that one of the most important conditions of coal carbonisation in horizontal retorts was that the largest possible charge of coal should be placed within the retort.

One method of comparing the effects of light and heavy coal charges was to analyse the spirit extracted from the gas by means of active charcoal. The higher quantity of phenols in the tar and liquor from a specific coal was a guide to the difference in carbonising in vertical as opposed to horizontal retorts.

The difficulty in isolating the products relative to a specific set of carbonising conditions led to the construction of an experimental plant on the new site at Fulham. This enabled the gas from two horizontal or one continuous vertical retorts to be routed to a train of condensers, washed and purified. Inter alia it was demonstrated that the higher thermal yield south of the river could be explained in terms of the hydraulic mean depth of the retorts.

Other early investigations included the analysis of waste gas as a guide to coal gas leakage; the use of the waste heat boiler as a measure of the volume of waste gases leaving the retort setting; and distinguishing between therms from coal gas and water gas in steamed vertical retorts.

In 1933 a step back was taken from the gas making process to report extensively on the effect of preparative processes, such as screening, mixing and blending on the carbonisation of coal and the quantity of coke (4).

Although there was a wealth of scientific information on this subject it was not easy to insert the necessary facilities into the coal handling arrangements of London gas works. Two such plants were described, however, as being under construction at Beckton and Southall. The latter incorporated a Salerno low temperature carbonisation unit for the production of semi-coke.

Two years later Pexton produced his classic paper on Hydrocarbon Enrichment Value (HEV) known as the 'Pexton Yardstick' (5). This simple concept in which the thermal yield of gas (on an inert-free basis) per ton of coal above a datum of 318 Btu/sft3 soon came to be used by all interested in coal carbonisation. In the absence of coal gas leakage out of retorts, the HEV is an index of the cracking conditions within the retort, the highest value indicating optimum conditions.

The concept was also widely used in carburetted water gas manufacture and in economic studies on carbonisation involving benzole removal and quality of coke produced.

The Gas Industry was always vitally interested in establishing the most economical use of fuel on the gas works. In 1943 Pexton delivered a paper (6) to the London and Southern Juniors on co-ordinating the information obtained on the fuel consumption of different carbonising systems.

He considered changes in the design of continuous vertical retorts in the period 1920-1940 and reported that the efficiency of gas production had increased from 54% to 64% and predicted an increase to 70 per cent. This increase was achieved by a 37 per cent reduction in the combined requirements of fuel for heating the retorts and in direct-fired boilers. The reduction in the former was brought about by using the sensible heat in the coke to pre-heat the secondary air. This also served to reduce the temperature of the structural steel at the bottom of the retort setting.

In that paper there is reference to tests being carried out by Burns, Daroux, Haffner, Badger, Weston, Exell and Donelly, and to a novel form of presenting the data, stemming from consultation with Silver. Opening the discussion, T. C. Finlayson observed that ' Dr. Pexton is regarded by plant designers as the chief test pilot of modern carbonising installations, and his expert and incisive analyses of performance have proved of great value'.

Later in 1943 Haffner and Weston (7) published the results of an interesting experiment in which they quenched the charge in a row of four Glover West retorts due for demolition. This provided some useful information on the mechanism of carbonisation in continuous vertical retorts obtained from examination of the charge which was a coherent monolith capable of holding together even after the supporting wall had been partly removed.

Use was also made of tallies introduced periodically into the retort prior to the quenching operation. This technique was to be improved on after the war when radio-active tracers became available (8).

It is interesting to note that in contributing to the discussion on the Haffner/Weston paper, Dr. King, of the Gas Research Board, said he would like to see the work extended by the Board, which was naturally interested in all the research work carried out by gas undertakings.

Work on the performance testing of carbonising and CWG plants continued into the 1950s under the leadership of C. H. Lewis. In addition to the work on coal travel referred to above, carbonisation using a carrier gas was investigated (9) and the work culminated with performance testing of the Gas Integral plant at Kensal Green (10), a total gasification plant with four vertical retorts about 20 feet long surmounted on a modified CWG plant. The weakly-caking coal was carbonised at about 700°C, the reactive semi-coke passing into the generator. It was soon after this that the Lewis Group was transferred back to North Thames and became involved in the introduction of both cyclic and continuous oil gasification plants into the Board's operations.

Carburetted Water Gas

Dr. Griffith joined the research team in 1925 and took up the investigation into the relationship between the composition of gas oil and its value for enriching blue water gas. He devised an analysis which separated the gas oil into paraffins, unsaturateds, aromatics and naphthenes and, with the aid of a small cracking furnace, demonstrated that the paraffins and unsaturated aliphatics were the valuable components of gas oil as an enricher. The suppliers agreed to price the feedstock based on this evaluation.

Full scale performance tests were carried out with the support of the Station Chemists at Nine Elms, Bow Common and Staines, and gas yields agreed with those obtained in the laboratory. The work on evaluation was published in 1929 (11) and subsequently Griffith produced a monograph on Water Gas (12).

The CWG process was, of course, investigated extensively by Dent at Leeds, the work being published under the auspices of the Joint Research Committee (13,14).

Refractories

In order to obtain a better working life for retorts and coke ovens it was essential that the refractory materials used in their construction should be of the highest quality. New and used materials were therefore systematically studied in the laboratory and, in particular, retort settings were examined during demolition at the end of their useful life.

One subject which received attention was flaking in continuous vertical retorts (62). It is interesting to note that the work on refractories led to the development of catalysts for cyclic gasification (63) and to the development of X-ray diffraction methods of analysis which will be referred to later in this account.

Coal Tar Hydrogenation

This is a facet of the work at the Fulham Laboratories about which very little was published due to commercial agreements. The Gas Light and Coke Company became interested in a number of projects directed towards production of motor spirit. These included the Bergius Process for the hydrogenation of coal. This marked the birth of all work on hydrogenation and catalysis but hydrogenation of coal was soon abandoned because of problems with anthracene oil. Laboratory work on creosote hydrogenation continued.

However, in 1928 Hollings and Griffith went to Konstanz to observe methods of hydrogenating tars under high pressure, as practised by Holzverkohlung I.A.G. (HIAG). They were producing charcoal from wood on a large scale and using the wood tar for their hydrogenation experiments in autoclaves.

The Company's interest stemmed in part from their involvement in low temperature carbonisation. The Government was encouraging the production of indigenous oils and smokeless fuels and the GLCC commissioned a trial plant at Richmond to produce a coke suitable for open fires. It was the tar from this plant which formed the basis of the hydrogenation experiments.

Chemical Reactions Limited was a joint company formed with HIAG to pursue this work and a team was built up at Fulham to operate high pressure equipment for treating British tars with the HIAG catalyst. One of their chemists came to Fulham and Burns went to Konstanz for a year. Small scale work was started at Fulham with Hill, Plant and their team.

Some of the work on silica promoted molybdenum catalyst was published in a series of papers to the Royal Society in 1934 (55, 56, 57). Griffith and his co-workers observed the existence of chemisorption as the essential factor in a catalytic process. Similar phenomena were reported by Professor Taylor in America just before any of the Fulham work was published. It was not the first time, and certainly not the last, that scientists working independently of one another in different parts of the world arrived at the same stage at the same time. Further papers by Dr. Griffith were published in the Transactions of the Faraday Society in 1936 and 1937.

The hydrogenation of British coal tars did not appear promising because of the high aromatic nature of their composition, but it was decided to try a continuous flow unit as opposed to the batch experiments in autoclaves.

Coke

Mention has been made of low temperature carbonisation at Richmond, with the object of producing an open fire coke. Dr. Eaton was Station Chemist at the time and he subsequently led a team at Fulham investigating all aspects of coke production and its efficient utilisation in coke burning appliances. This led to a series of publications by Eaton (58, 59, 60) and to the production of the Fulham Grate in 1939, which marked a significant phase in the domestic utilisation of coke.

Interest in coke began at the Fulham Laboratory in 1927, with a paper by Hollings and Siderfin (61) on 'Coke in Relation to some of its Industrial and Domestic Uses' and ended in 1945 when the Coke Laboratory under Eaton was transferred to Watson House.

Partial Combustion of Oil

In order to avoid the high capital charges associated with coal plant, the Gas Light and Coke Company experimented with the partial combustion of oil. The process known as the GLC Process employed the phenomenon of the cool flame. Having a high gravity and a low flame speed the proportion of this gas that could be added to conventional gas was strictly limited. Maccormac (69) was responsible for the development of the process which was operated in two small units at Southall and Southend.

2.4 Gas Treatment

Cooling and Condensing

Reference has been made to the scientific investigation of cooler-condensers by Carpenter. The first contribution from Fulham was a paper by Pexton and Hollings (15) in 1929, quantifying the advantages in terms of surface area required for a given duty of the modern battery or horizontal water-tube condenser. Charts were included giving the area of cooling surface required to cool gas between specified limits. The object of this work was to ensure that the gas was cooled as much as possible to increase the efficiency of ammonia recovery.

To improve the understanding of the cooling and condensing process, Hollings and Hutchison (16) reported in 1935 on a series of tests on an installation of horizontal water-tube condensers. By careful analysis of results and making allowance for the water film resistance from known correlations, they established the dependence of the gas film coefficient for heat transfer on gas velocity and gas temperature.

They observed that if the heat transfer coefficient was based not on temperature difference but on the difference in vapour pressure of water, the value was practically constant throughout the condenser. This is because the problem is one of simultaneous heat and mass transfer and due to the high latent heat of water the mass transfer effect predominates.

The disadvantage of expressing a heat transfer coefficient in terms of vapour pressure difference was that it could not readily be combined with the four other coefficients and in 1947 Silver produced a simpler empirical method more readily applicable to the analysis of test data.

Silver was originally a works chemist but realising his potential Hollings brought him into the Research Laboratory. In 1934 he had pioneered the theory of mass transfer with chemical reaction and 13 years later he presented another classic paper to the Institution of Chemical Engineers on Gas Cooling with Aqueous Condensation (17). The simple ploy that he used was to equate the ratio of total to sensible heat transfer coefficient with the total to sensible heat capacity of the saturated gas.

Two years later in the United States Mickley (18) produced a similar 'total heat' method for the air-water system as a basis for cooling tower design.

The assumptions implicit in the Silver and Mickley 'total heat' methods were acceptable for situations where the saturation temperature of the gas did not exceed about 160°F, i.e. with carbonisation processes. The strain was felt when carrying out performance tests on carburetted water gas plant (19), where the saturation temperature was in the region of 180°F. With cyclic oil gasification processes the saturation temperature could be as high as 190°F (20).

Hollings and Hutchison had registered the need to take into account the partial pressure of the non-diffusing gas at higher temperature as in the Colburn and Hougen method

(21). A design method as rigorous as that of Colburn and Hougen, but which could be applied in reverse to the analysis of performance data from cooler-condensers, was proposed by Cribb and Nelson. A series of papers by these authors describe the development and application of the method (20, 22, 23, 24). The method did not assume that heat and mass transfer kept in step, a fact known not to be true. Indeed the conditions under which fog would form could be predicted. However, like the League of Nations building, by the time the task was completed there was no further requirement for it. The era of high pressure continuous reforming had arrived and, for better or worse, the design of the ancillary plant reverted to the contracting industry.

Before leaving this subject, the importance of a good supply of cooling water for the cooling and purification of manufactured gas cannot be over-estimated. The performance of water cooling towers was studied by Hutchison and Spivey (25) in the late 1930s. In making tests on commercial cooling towers they observed that their performance was well below what had been expected of them. Further the spray they emitted created both a nuisance and a corrosion hazard to adjacent plant. They therefore designed an experimental forced draught cooling tower with wooden grid packing and trough distributors. The performance of the new design was far superior whether in terms of heat or mass transfer to that of the traditional type with the further advantage of eliminating the emission of spray. This experimental tower formed the basis of many full-scale designs.

In cooling towers as in washer coolers the air and gas are in direct contact with water. There was some discussion in the 1950s as to whether there was a significant liquid film resistance in these circumstances. Work at Fulham (26) indicated that although there was a measurable liquid film resistance it could be ignored for design purposes.

Ammonia Recovery

Reference was made in the early part of this paper to the chaotic state of ammonia recovery when Hollings was appointed in 1924. The first problem to sort out was the cooling of the gas upon which the efficiency of ammonia recovery depended in the sense of determining the degree of removal achievable. The approach to equilibrium depends on the design and operation of the washers and this was the next unit operation to receive attention.

It was necessary to reduce the ammonia concentration in the gas to a low level to ensure satisfactory operation of the oxide purifiers, the next stage in the purification train. Excessive ammonia led to side reactions which interfered with the purification process and depreciated the value of the spent oxide. It was also desirable to keep the volume of liquor used for washing to a minimum in order to obtain a high strength of liquor. This reduced the costs of concentrating the liquor prior to transport and disposal.

The first and most frequent phase of the investigation into gas washing was reported to the Institution of Chemical Engineers in 1934, in two classic papers by Hollings and Silver (27, 28). The second paper by Silver set down the theory of mass transfer with chemical reaction and the equations developed can be identified with those appearing in chemical engineering textbooks published in the United States some years later. Many gas engineers since that day will have been introduced to the mysteries of qk and 'the number of transfer units' (Kg a/V) and slip.

Appreciation of this led to major improvements in the design and operation of the washers. It explained why simple tower scrubbers were totally unsuitable for ammonia removal and why they were superseded by the rotary washer and the more elegant multi-stage static washer. As Hollings observed in his earlier paper, it had been necessary to determine the equilibrium data for the system ammonia, water, carbon dioxide, hydrogen sulphide, the definitive publication being that by Pexton and Badger

(29). The low vapour pressure of ammonia over heavily carbonated solutions indicated that if weak liquor were to be used for ammonia recovery a combination of co-current and counter-current gas-liquid contacting was the optimum.

As Sir Kenneth Hutchison noted in his tribute to Stuart Pexton (30) 'Fortunately no one yet knew how complex this system is, due to the slow hydrolysis of carbon dioxide and the existence of carbamate as well as carbonate in solution'. This complexity still bedevilled the Station when it set out to develop a process for the removal of carbon dioxide at atmospheric pressure, based on the reaction between ammonia and carbon dioxide in aqueous solution (31,32).

Silver's theory also pointed the way to the selectivity in the rate of absorption of carbon dioxide and hydrogen sulphide which became the basis of a number of liquid purification processes.

Silver's last contribution to the theory of mass transfer with chemical reaction was in a paper to a Symposium on Absorption, sponsored by the Institution of Chemical Engineers in 1954 (34). He was still producing new ideas. Cribb took over Silver's group when he retired and on reading through his chemical laboratory record books of the 1930s found the elements of the penetration and surface renewal theories of gas absorption later associated with Higbie and Danckwerts.

The tradition which Silver established was upheld in the later work at LRS on acid gas removal processes. As we shall learn later it was this work that indirectly led to the establishment of the Maths and Computing Division.

Benzole Recovery

There were two methods for the removal of benzole from coal gas, active carbon and oil washing, and the Fulham Laboratory played a significant part in the development of both. Reference was made earlier to the fact that Sir Harold Hartley had advocated the use of active carbon for coal gas clean-up based on his wartime experience. The advantage of the active carbon process compared with the oil washing process was that it eliminated the necessity for extensive rectification of the crude benzole recovered. It was for this reason that the Gas Light and Coke Company decided in 1924 or thereabouts to make a thorough investigation of the possibilities of the process.

A pilot plant was built at Beckton to study the Bayer process of recovering benzole from gas by active carbon. However, there was very rapid loss of activity due to accumulation of gummy deposits and a poor recovery of benzole per lb of carbon. The process in that form was therefore abandoned and a return made to the laboratory.

It was during these laboratory investigations that Pexton hit on the idea of passing the regeneration steam in the opposite direction to the gas. By this means the gummy deposits were removed instead of being carried further into the bed. Another improvement to reduce the fouling was to start the desorption from cold in the presence of live steam and to bring on the steam heating coils later in the regeneration cycle.

Based on these findings a commercial unit was built at Harrow Works in 1928. The tenfold improvement in both cycle life and recovery of benzole per lb of carbon was reported on by Hollings, Pexton and Chaplin (34). They acknowledged the not inconsiderable effort in this investigation put in by Banks, Voss, Ravald and Ware. The removal of naphthalene and hydrogen, normally present in coal gas, contributed materially to the life of the active carbon.

Following the success of the Harrow plant, units were commissioned at Beckton in 1932 and Bromley in 1939. These plants were charged with active carbon imported from Germany but reactivated at West Thurrock by British Carbo Union.

The performance of the Beckton plant was described in a paper by Hollings and Hay (35), which also focussed attention on the benefit of partial organic sulphur removal accompanying benzole removal. In this respect, active carbon was likely to have an average efficiency of 80 per cent compared with 40 per cent for benzole removal by oil washing. Of course, the quality of the benzole recovered is correspondingly poorer in terms of sulphur content.

One difficulty met with at Harrow and Beckton was the severe internal corrosion of the coils embedded in the carbon. These coils contained high pressure steam during distillation and cooling water during adsorption. The method of dealing with this problem at Bromley by using pressurised water on a closed circuit was described by Hopton (36).

The other method of recovering benzole by washing gas with gas oil or a similar solvent was introduced on a considerable scale during the first world war. After the war benzole recovery declined but picked up again in the early 1930s as a result of fiscal incentives. A disincentive was the fact that the benzole from continuous vertical retorts was of inferior quality.

During the second world war benzole recovery again assumed vital importance. The advantage of the oil washing process in this respect was that special emphasis could be given to the high recovery of toluene. A flexibility not possible with the active carbon process. The methods of design and testing of oil washing plants developed in the Fulham Laboratory and set down in the paper by Silver and Hopton (37), were circulated throughout the Industry. They formed the basis of the survey of benzole plants on gas works up and down the country, carried out during the war by the Fulham staff on behalf of the Advisory Committee on Benzole Recovery. Gooderham and Voss were prominent in this work, the somewhat lighter side of which is described in PART 1.

Organic Sulphur Removal

Although the statutory obligation to remove hydrogen sulphide from distributed gas is long standing, the legal requirement to remove organic sulphur compounds was relaxed, thus enabling the objectionable process of lime purification to be abandoned in favour of iron oxide. In 1934, however, the advantages of removing organic sulphur in terms of the reduced corrosion of appliances was becoming apparent (35).

In the Hollings and Hay paper referred to in the previous section, application of the oil washing process was forecast based on the observations of Hutchison. Three years later in 1937 the IGE held a mini-symposium on the Removal of Sulphur Compounds from Gas, all three papers being provided by staff of the Fulham Laboratory.

The first paper by Hollings (38) was in the nature of a review of the available processes and their costs. The paper by Hutchison (39) described the adoption of the oil washing process for sulphur removal culminating in the construction and operation of a plant at Kensal Green Works.

This plant was designed on the basis of laboratory experiments with no intermediate pilot plant, achieved rated output the day after commissioning and had continuously operated at this level at the time the paper was presented some nine months later.

The oil circulation rate required for a high level of sulphur removal was several times that for benzole removal and the steam required for stripping was kept within reasonable limits by operating the still under vacuum.

The final paper in the trilogy by Griffith (40) introduced the catalytic process for sulphur removal. Both the oil washing process and the active carbon process reduced the level of carbon disulphide and thiophene but had no effect on carbon oxysulphide. If therefore it was desired to reduce organic sulphur to a low level (less than 3 grains/100 sft3) the carbon oxysulphide problem had to be tackled.

Carpenter (41) had described the history of catalytic purification which led to a process adopted by the South Metropolitan Gas Company. This was based on the catalytic hydrogenation of sulphur compounds to hydrogen sulphide, using a nickel subsulphide catalyst, but was not widely adopted in the Industry owing to its high cost.

The Gas Light and Coke Company took a fresh look at the catalytic means of removing sulphur compounds in 1936. The reasons underlying this decision are quite interesting. A small team under Griffith, including Plant and S. G. Hill, had developed an interest in catalysis following a decision in 1928 to investigate the catalytic hydrogenation of coal tar. When the gum problem hit the Company in 1931, most of the Fulham staff were called in to tackle the problem. One of the ideas followed up was catalytic treatment to convert nitric oxide (the cause of the trouble) into ammonia. Nickel subsulphide catalyst, the compound originally used by Carpenter, proved effective.

The GLCC process differed in two respects from the Carpenter-Evans process. The support for the catalyst was china clay which unlike the broken firebrick support did not catalyse gum forming reactions. Secondly, the process was based on the catalytic oxidation of the sulphur compounds to sulphur dioxide and some trioxide subsequently scrubbed out with soda ash solution.

In 1932/3 a small scale plant was operated for the catalytic removal of nitric oxide and by 1934 sufficient data had been obtained for Plant to design a full-scale unit. This was built at Harrow, together with a plant for manufacturing the catalyst. It was whilst the Harrow plant was being designed that the survey of sulphur removal processes was conducted.

A temperature of 150°C was sufficient to eliminate nitric oxide but by raising the temperature to 250°C carbon disulphide and carbon oxysulphide could be oxidised and removed from the gas. The emphasis on the Harrow plant thus moved from nitric oxide to organic sulphur removal. By now the catalyst team had been joined by Bruce, Newling and Morcom and in 1935 Griffith published his first book on catalysis (42).

Unlike the Carpenter-Evans process where the gas was raised to the reaction temperature of 430°C by external heaters, the GLCC process relied on heat generated on the catalyst by the combustion of hydrogen and oxygen. In fact the process could be controlled accurately by close control of the oxygen concentration and in 1950 the process was completely automated, based on the magnetic property of oxygen (43). The idea was suggested by Morcom but developed by an outside company.

The plant was kept in good working order throughout the war and supplied low sulphur gas to factories requiring this for the bright annealing of cuprous metals.

Work on the process continued after the war and in 1948 Plant and Newling (44) indicated some of the changes in plant design and control that would be made in future plants based on experience at Harrow. In 1947 Marsh joined the team and was involved in demonstrating why the process was not capable of removing thiophene (45).

Although the process was predominantly one of catalytic oxidation, traces of hydrogen sulphide were produced, due to the high concentration of hydrogen, which required removal. This led to an investigation of methods of fine purification. The last paragraph of the Plant/Newling paper referred to the design of a plant to treat 7.5 million sft3 of gas per day which would be built as soon as conditions permitted. This was to have been erected at Bromley-by-Bow, but following a succession of postponements, due to steel shortages in the early 1950s, it never was built.

Removal of Hydrogen Sulphide

Although it was appreciated that the process for the removal of hydrogen sulphide by means of naturally occurring iron oxide was one in need of scientific investigation, the preceding processes had to be tackled first. It was necessary to avoid contamination of the oxide with tar and excess ammonia.

The first record of this process being under investigation at Fulham was in the 1935 paper by Hollings and Hutchison (16). This described the Gas Referees test and assessed its sensitivity as 1.5 ppm of H_2S. It reviewed the levels of H_2S in crude gas and stressed the difficulties of investigating the process due to the large inventories of purification material representing an average residence time of two years, the periodic removal and addition of material during this time, and the discontinuous nature of the operation.

Because of the need to condition new oxide, the classic counter current operation was not appropriate and the conventional method that had been developed of rotating oxide boxes was described, together with some typical costs for oxide purification. The first complete account of the nature of the reactions between hydrogen sulphide and the various forms of iron oxide and between oxygen and the sulphides of iron was given by Griffith and Morcom (46). They prepared seven forms of ferric oxide and identified the alpha and gamma monohydrates as being the two forms which reacted immediately and rapidly with hydrogen sulphide.

Important variations in the reactivity of various forms of iron oxide were reported by Griffith and Hopton (47) and the whole subject was extensively reviewed by Hopton in 1948 in a paper (48) to the Southern Association of Gas Engineers and Managers.

Amongst the subjects considered were the effect of temperature, pH and porosity on the activity of oxide, what makes a good bog ore, and the value of manufactured materials such as Luxmasse and copperas-lime nodules.

This special form of oxide developed at Fulham (49) had a high initial cost but had distinct advantages for peak load purification and final clean up. It was used for this purpose at Harrow to remove traces of H_2S produced in the organic sulphur removal plant.

Another line of research being pursued at Fulham was the use of iron oxide pellets in an experimental vessel to and from which material could be added and removed without interrupting the gas flow.

Finally in this review Hopton considered the design and operation of purifiers and the evaluation of purification materials, with particular reference to the test that he developed with Griffith.

It was about this time, i.e. late 1940s, that there was a fear that the export of iron-bearing ores from Denmark would be restricted and a world shortage of sulphur was forecast. The former reinforced the need for the Industry to change over to the use of more active specially prepared forms of oxide. In conjunction with the latter event, this inspired two developments, namely the solvent extraction of oxide (50) and the preparation of an artificial purifying material from copperas and ammoniacal liquor (49).

It would perhaps be more true to say that it initiated a fresh look by the Research Station at these two processes which had previously been looked at by the Industry and rejected because of technical or economic problems.

In 1952, the year of his retirement, Hollings described the work on these two processes in his paper entitled "Progress in Gas Purification" (49). The improvement in the solvent extraction process was to substitute toluene for carbon disulphide as the solvent. By controlled crystallisation it was possible to obtain sulphur of 99.8 per cent purity operating on the pilot plant scale.

The breakthrough in the second process was to obtain complete precipitation of iron from solution by ensuring an excess of sulphide ions in a second stage and a strong solution of ammonium sulphate by using solid copperas and concentrated ammoniacal liquor. The precipitated iron compounds, when filtered out, mixed with peat and oxidised gave a very active purifying material.

A full-scale plant designed to produce 11,000 tons/year of purifying material was designed and erected at the Bromley-by-Bow Works. Unfortunately, unlike the Kensal Green oil washing plant, this was an instance where proceeding to the full-scale without a pilot or semi-commercial plant proved a mistake. Ironically, it was the precipitation of the iron as sulphide, which had clinched the success of the laboratory experiments, that proved the downfall in continuous operation. After about 3 hours operation of the rotary vacuum filter, the cloth became blinded with finely divided sulphur and the rate of filtration declined to an unacceptable level.

The process was made to work technically by substituting soda ash for ammoniacal liquor but as is so often the case the economic trends, on which the process was evaluated, reversed. The availability of Danish bog ore did not decline. The sulphur shortage was transitory, so the value of ammonium sulphate weakened, whereas the cost of peat escalated appreciably.

Although this project would no doubt be classed as a failure, it was in the nature of an insurance policy against the trends predicted and could have been made to work had the economics remained favourable.

By the mid-fifties most of the problems of the removal of H_2S in large static iron oxide purifiers had been thoroughly investigated. The trend as indicated by Hollings was towards tower and tower box purifiers to economise in ground space and to reduce the labour content of the operation.

These objectives would have been achieved more effectively by a liquid purification process. The GLCC had looked at various processes over the years and even developed to the pilot plant stage a process based on ammonia. The required breakthrough was not achieved. Most processes were bedevilled by corrosion and/or undesirable side reactions resulting in permanent loss of reagents and effluent problems.

Following investigations it was decided in 1948 to install the Koppers Vacuum Carbonate Process at Beckton for 'scalping' the gas from two horizontal retort houses. The process appeared to be free of the above disadvantages. It was, however, approaching the end of the carbonisation era when the plant was commissioned in 1957. As a forerunner of things to come it was the mechanical features of the plant not the process that provided the problems as described by Cooper and Johnson (51). The interest in liquid purification processes continued for trace removal and in some cases for cleaning up refinery gas used for enrichment. The use of liquid purification (sweetening) processes was well established in the oil industry, principally based on absorption desorption processes such as ethanolamine. These, however, were not capable of reducing H_2S to the statutory limit. For this purpose only reagents with a zero partial pressure of H_2S above them could be considered.

A considerable amount of research led to a variety of patents covering a wide range of alkaline solutions and suspensions in which the acid gas was initially absorbed in the alkaline medium and then fixed by reactions with heavy metals, such as zinc or copper (52).

The alternative method of 'fixing' the sulphur absorbed as alkaline hydrosulphide ion is to oxidise it to elemental sulphur. Various processes based on possible oxidation-reduction systems were investigated, but the success in this field was achieved by Dr. Nicklin and his team at North Western Gas who developed the Stretford Process, which became well established for a range of applications.

The Formation of Nitrogenous Gum

In the early 1930s the Gas Light and Coke Company, in common with other gas undertakings, ran into the gum problem. Over the years there had been a marked decrease in the number of blocked service pipes and appliances due to naphthalene, water or rust, but this new problem manifested itself as deposits of gummy material in the most sensitive units, namely pilot lights, adjustment valves and governors of the more modern appliances.

At the time the investigation began at Fulham in January 1932, it was not known whether the phenomenon was due to a change in the character of the gas or to a higher standard of performance demanded by the new appliances. By the time Hollings (53) presented his classic paper on gum formation to the IGE in the Autumn of 1936 (the first award of the Institution Gold Medal to one of the Fulham Laboratories' team) the problem was well understood.

Virtually all the laboratory staff had been involved at one time or another and the ramifications went far beyond the gum problem itself.

The formation of gum was due to the reaction between traces of nitric oxide, oxygen and certain conjugated diolefins, notably cyclopentadiene (54). But it was principally the rate and place of the formation and removal of the gum that controlled the nature of the problem.

Experience showed that if the gas distributed contained less than 20 grains/million cubic feet there was unlikely to be trouble, but if it contained more than 100 grains/million cubic feet complaints were almost certain. Since the average concentration of nitric oxide in gas leaving the purifiers was 0.5 parts per million and this could give rise to 250 grains of gum per million cubic feet, the sensitivity of the problem can well be appreciated.

Nearly all coal gas and carburetted water gas contained sufficient unsaturated hydrocarbons to react with the traces of nitric oxide to form gum, therefore considerable importance was attached to the concentration of the latter. As Hollings pointed out in his presentation, 'the standard of purity in respect of nitric oxide with which we are now concerned is 30 times as stringent as the standard in respect of hydrogen sulphide, with which the Industry is so familiar'.

The prevention of gum formation could therefore only be achieved by severely limiting the introduction of nitric oxide into the gas or removing it before it had a chance to react. Bearing in mind the exceptionally low level of purity required the former was difficult to achieve and indeed monitor. The normal processes of purification removed about half the nitric oxide, the only effective stage being sulphided material in the oxide purifiers. The one certain method was to install a catalytic reactor in which the nitric oxide was reduced to ammonia. This in fact was achieved by the Harrow plant and other plants whose primary role became organic sulphur removal.

Such processes were, however, going to take time so the short term solution was to allow the gum to form and remove it before the gas went on to the district. Undoubtedly the step which exacerbated the problem was the decision of the GLCC to distribute dry gas. The gum reactions were inhibited by certain surfaces and usually were not initiated until the gas passed into holders where the surface to volume ratio was very small. Even here an induction period was necessary and the rate of settling of the gum particles was significantly enhanced by the presence of condensing water vapour. It was the installation of gas drying plants upstream of the holders which had negated this important step in the gum removal process.

Not only did realisation of this important function of the holders dictate the need to switch the gas drying plant to outlet holder but also indicated the need to store the gas for as long as possible, to avoid arrangements of holder connections that enabled the gas to pass from inlet to outlet without adequate residence time and the possible need to admit live steam to holders in very warm weather.

By attention to good housekeeping at the gasmaking end and a combination of some or all of the techniques outlined above the gum problem was overcome. It is salutary, however, to note that 40 years later oxides of nitrogen were still commanding the attention of the Industry.

2.5 The Holborn Explosion

In 1928 there was an explosion in a large Post Office duct in Holborn, which blew off manholes and caused a great deal of damage to shops and premises (64). The resources of the entire laboratory were called upon to investigate this incident, which developed into a legal battle with two eminent Professors appearing on opposite sides. Professor Bone, for the Company, sought to prove that sewage gas was responsible whilst Professor Wheeler, for the Post Office, named coal gas as the culprit. The matter was finally settled out of court (64) for reasons as it happened unconnected with the scientific evidence - i.e. the discovery and identification of a cigarette lighter that an unfortunate victim of the explosion had taken down a manhole.

2.6 Gas Works Effluents

The treatment of gas works effluents refers to an area of work that began in the first period covered by this narrative, but extended well into the second. It is reviewed here rather than later because the work was initiated by concern over the disposal of effluents from traditional coal carbonisation processes.

It was customary for the Gas Industry to discharge the effluent from coal carbonisation processes into sewers where, in diluted form, it was conveyed to the sewage works for treatment and subsequent discharge to a watercourse (71). Although the effects of the effluent on the biochemical processes used at the sewage works had been in dispute for some years, it had been generally agreed by both gas and sewage authorities that this was an acceptable method of disposal.

In the years following the Second World War new legislation materialised in the form of the Rivers (Prevention of Pollution) Act 1951, and it was expected that in time further controls would be imposed on the discharge of industrial effluents, an expectation that was proved to be justified. It was clear that in any future expansion or reorganisation of the traditional gas industry, new methods of treatment would be needed to reduce the load imposed by gas works effluents on a receiving sewage works, or even to permit direct discharge to a river. Any effective method of treatment would involve the removal of phenols and thiocyanate, by physical methods such as extraction, by chemical treatment, or by conversion to harmless products. Extraction methods alone had proved elsewhere to be complicated and expensive; disposal by evaporation was extravagant in fuel and open to other objections, and chemical methods were known to be costly.

The possibility of oxidising gas liquors biologically on trickling filters in the absence of sewage had been studied earlier, notably by Fowler and Gardiner. From their pioneer work, however, it appeared that the volume of filter required to treat appreciable quantities of liquor was excessive. But interest in the potentialities of biological processes was revived by reports after the Second World War of the successful treatment in Germany of similar liquors by the Magdeburg-P process, a biological system in which certain nutrients, particularly phosphate, were added in order to meet the needs of the micro-organisms employed. In his 1951 Memorandum to the G.R.B. Advisory Panel, Badger (72) accordingly recommended that "steps should be taken to obtain all possible information about the Magdeburg-P process, with a view to making practical tests in this country", and subsequently work began at LRS on a small scale in November 1951.

The earliest studies in vessels of 3-14 litres capacity were on solutions of phenol and thiocyanate and on spent liquor. The micro-organisms employed originated in some earth removed from beneath a compost heap in Badger's garden. During these studies some of the factors affecting the biological process were confirmed or established (73). It was shown that by the use of suitable micro-organisms and the addition of nutrients considerable reductions could be achieved in the phenols and thiocyanate in undiluted spent liquors. The work developed through stages of bench and small pilot plant units, and included studies of aeration systems, liquor type, flow rates, nutrient requirements, dilution effects, and sludge separation and disposal. During the course of the work the team was strengthened by the appointment of Eileen Pankhurst, a microbiologist, who was successful in isolating and characterising various types of micro-organisms from the mixed cultures used. By 1962 various phenol and thiocyanate oxidising organisms had been freeze-dried at Fulham for future use, a precaution which was to bear fruit some 15 years later when interest was revived in the treatment of gasification effluents.

The laboratory and pilot plant work on spent liquor culminated in 1960 in the construction of comparatively large plants at Southall, in which up to 5000 gallons of spent liquor per day were treated in two parallel streams employing three different systems. In one stream the first stage employed surface aeration, while a second stage used diffused air. In the second stream each of the two stages consisted of a natural-draught tower filled with a commercial plastic packing. Each stage of the two streams was a module of a full-scale unit so that scaling-up effects were minimised.

The results of the Southall work (74) confirmed earlier studies that it was feasible to remove about 95% of the polluting matter from spent liquor by biological means on a gas works site, at costs which were similar to the likely charges for disposal to a sewage works. During this work, and earlier studies at Fulham, a relationship was identified between the loading of the system and the efficiency of removal (75,76), thereby establishing design criteria for full-scale plant. In addition to the mainstream work on spent gas liquor, studies were initiated on liquor from a cyclic catalytic gasification process (ONIA-GEGI), the main constituent of which was thiosulphate. As a result the operating conditions were established for the biochemical treatment of effluents containing this pollutant (77).

The work on biochemical treatment of effluents was supplemented by various peripheral studies, including the effects of ozone, chlorine, electrolysis, active carbon and ion exchange. Furthermore the work required analytical support during which advances were made in the techniques of estimating individual phenols and various organic acids, many of which had not previously been identified as constituents of spent liquors.

A major assignment undertaken was a study of the biological treatment of effluents from the Lurgi Gasification Process. This was part of the work of the Joint Study Group of the Gas Council and the National Coal Board, set up to evaluate the economic feasibility of a notional plant at Newstead, on a new site which would discharge to the River Trent. The laboratory was able to use its expertise, acquired during its work on spent gas liquor, to mount a successful study conducted in collaboration with the NCB. From results of the work designs were produced of full-scale treatment units to treat the output of the proposed plant, so that it would be acceptable for direct discharge to the river (78).

In the event, the Newstead project was dropped and the full-scale plants were never built. This outcome typifies the immediate fate of the work on effluent treatment, for as the investigations came to fruition so the Industry changed to manufacturing techniques based on oil that presented none of the effluent problems of coal-based processes. But it would be wrong to assume that this work was to no avail. Later, interest in the modified Lurgi Coal Gasification Process (the British Gas/Lurgi Slagging Gasifier), and the introduction of more stringent legislation forecast in the early 1950s, led to a resumption of effluent treatment work which drew heavily on the previous experience at LRS. This work is referred to in the account given in Period 2 of environmental work associated with the slagging gasifier.

2.7 Other Activities

It is not feasible in a paper of this nature to deal comprehensively with all the work carried out by the Fulham Laboratory since its inception. Many of the main aspects of gas production and treatment for which Fulham acquired a reputation have been described above, but other work was carried out on a number of closely related topics. The corrosion of gasworks plant and its prevention received attention from Dougill (65), Ravald (66) and Chilver (67). One always associates the name of Mills with calorimetry (68) and by coincidence, in later years his namesake, Dr. Alan Mills, was in charge of developing the LRS Compact Calorimeter.

Other items that have commanded the attention of the staff at Fulham during this period were the thermal decomposition of methane, gas drying plants, sealing oil for waterless holders, the cleaning of producer gas, and grit arrestors on CWG plant.

During the Second World War nearly all the Fulham staff were involved in problems arising from Government departments. These included the development of FIDO (Fog Investigation Dispersal Operation) using coke braziers, and the performance testing of benzole plants throughout the length and breadth of the country to maximise toluene production. These and other wartime activities have been described in more detail in Part 1.

Much of what was achieved in the first 30 years would not have been possible without the tolerance and understanding of other departments in the Gas Light and Coke Company, and its successor the North Thames Gas Board. In particular, one must mention the support of the Chief Engineer's Department.

PERIOD 2 - THE NEXT 30 YEARS

2.8 Introduction to Period 2

For most of this period the London Research Station was regarded as the Corporate Laboratory of the Industry, offering a range of specialist services to British Gas in general, and the R & D Division (later R and T Division) in particular. The programme of the Station was carried out within four technical Divisions, i.e. Analytical, Operations, Maths and Computing, and Physics, with support provided by the Services Division. The first three had their origins in aspects of the research programme prior to 1958, whilst the Physics Division resulted from the assimilation of the Basic Research Group into the Station.

As mentioned in the Introduction to Part 2 of this narrative the work of this Period (1958 to 1993) is best described by reference to the development of these four Divisions. Inevitably there are areas of work which overlap the two periods into which this Part has been divided. One example, referred to earlier, is the work on effluent treatment which spanned the years from 1951 to 1993, and which marked the beginning of the Station's involvement in the 'environment' in advance of the common use of the word in this context. Another notable example is work in the field of chemical and physical analysis which, eventually, was brought together to form the nucleus of the Analytical Division.

2.9 Analytical Division

Although the Analytical Division was really brought together formally only in 1966, the first overview of analysis as a whole started about ten years previously with a paper presented to an Analytical Congress in 1957, on the Application of Physical Methods of Analysis in the Industry (101). Later there were several papers presented to the IGE with an increasing emphasis on analysis as a whole and the integrated use of specialised instrumental techniques so as to make the best possible use of them for the Industry at large (102, 99,103, 89). The objective was to regard analysis as more than just producing results, but to consider the problem requiring the analysis, to interpret the results in the light of the problem, and to use the information gained for the wider benefit of the Industry.

Analytical Techniques

Over the years, a sound reputation for analysis was built up at Fulham. In the late 1920s and 1930s the Laboratory pioneered the development of many methods, e.g. for the analysis of fuel gases, gas oils and benzole and for the determination of nitric oxide, hydrogen sulphide and iron carbonyl (16, 79 to 86). Some of these stood the test of time for many years. For example the early work on H_2S determination (16) modified in the 1950s (87), continued to form the basis of a method adopted as a British Standard into the 1980s. Others were superseded eventually by advancing technology, but as examples of sound scientific work they are hard to match.

Most of the analysis carried out in the earlier days was in direct support of other projects in the Laboratory, but every effort was made to communicate them to the rest of the Industry. The "odd incident" led to new methods. One such, for the purity of naphthalene, arose from a study of why mothballs turned brown on the shop counter.

Up till 1948 virtually all the analysis carried out was based on "classical" or "wet" chemistry. With increasing interest in the cracking of gas oils for CWG enrichment, and later the use of naphtha for this purpose and for cyclic gasification, came the incentive for better methods of analysis.

The technique of infra-red absorption was in its infancy but with the help of Dr. H. W. Thomson, of Oxford (88), a single beam spectroscope was constructed. This was followed by an improved home-made instrument and the purchase of the first commercial instrument in 1958. These instruments were used for the analysis of benzole, naphthalene, effluents and odorants and later for the study of chemisorped species on the surface of catalysts.

From about 1953 two main streams of analytical development proceeded in parallel. The introduction of X-ray diffraction (XRD) led to a consolidation of inorganic analysis whilst the important field of gas analysis moved into chromatography, leading to wide ranging developments in this technique and others for gas and organic liquid analysis.

The X-ray diffraction equipment purchased in 1953 was for the characterisation of iron oxides and sulphides. However, the range of materials, examined to determine the crystalline compounds present, grew quickly. One of the more important applications was the identification of asbestos, and many thousands of specimens submitted by the Industry were examined. From the simple but important compound identification other applications evolved, including studies of carbon orientation associated with the flaking of refractories in retorts, and measurement of metal crystallite size and loss of activity in catalysts. After earlier work on cyclic catalysts the technique was heavily employed in the development of improved CRG catalysts for steam reforming of oil and for methanation. As a result of the increasing workload the X-ray camera gradually gave way to the powder diffractometer.

The technique was probably the first at LRS to make serious use of computers for both the automation of data collection and for the processing of data. This work was further exploited later to produce an automated quantitative analysis of the mineral composition of North Sea drilling core samples. A later addition to the X-ray diffraction equipment was a sophisticated high temperature stage. This could be used to study materials such as catalysts, sensors, and fuel cell components in-situ in flowing reactive atmospheres at temperatures up to 100°C, and to analyse the product gases by quadrupole mass spectrometry and gas chromatography.

A further venture into instrumental analysis was in 1956 with the purchase of ultra violet (UV) emission spectroscopy equipment. Although the initial requirement was for the determination of germanium in flue dust, since this fixed the selling price of the dust, the use inevitably extended to the rapid qualitative analysis of almost any unknown substance. Specific applications were for analysis of the slag from the Otto-Rummel coal gasifier at Bromley and for confirming that small deposits of soot in a burner were due to the decomposition of nickel carbonyl (90). By 1976 UV emission spectroscopy had been overtaken by more advanced techniques and the instrument was disposed of.

At the time of the introduction of physical instrumental methods of analysis it was customary for each laboratory to have its own "wet" chemistry bench. The close association between X-ray diffraction and catalyst development for cyclic oil gasification, led to an increasingly heavy workload of catalyst analysis including routine quality control work. This resulted in the appointment in 1963 of an analytical chemist to centralise the support work. In later years this chemical analysis section became part of the Analytical Division, and increased its scope and range of activity by equipping with instruments such as UV absorption, atomic absorption and various automatic instruments for routine analysis.

The first use of atomic absorption (AA) spectrophotometry was in 1963 when the technique was applied in its simplest form to the determination of nickel and iron carbonyls in gas (91). Later it was more generally applied to the determination of trace metals in solution. The equipment was relatively inexpensive and well within reach of smaller laboratories. With the developing role of LRS as a centre of analytical expertise, a dedicated instrument was purchased in 1969 to gain familiarity with the technique and, at the same time, to extend the facilities for trace analysis. Subsequently there were three instruments in regular use.

Aware of the developments in X-ray fluorescence spectrometry for the rapid elemental analysis of solids and liquids, some XRF equipment was cannibalised to make a primitive XRF camera. By 1966 commercial development had stabilised and, since the technique appeared to have many advantages over UV emission for specific purposes, a semi-automatic spectrometer was purchased. The confidence was justified and the instrument was used extensively for the quantitative analysis of catalysts, metals and oils, and the qualitative analysis of many thousands of miscellaneous samples. A second instrument incorporating a new type of detection system and a mini-computer was then purchased. This instrument reduced the time for qualitative analysis from hours to minutes, and XRF continued to be exploited, especially for rapid qualitative and semi-quantitative analysis until the Station closed. The increasing need for environmental inorganic analysis resulted in the acquisition of transportable equipment capable of soil surveys on site.

The X-ray equipment was supplemented by a transmission electron microscope (TEM) in 1968 and access to the Watson House scanning electron microscope/electron probe microanalyser (SEM) was used for the examination of metallurgical samples, catalysts, cores, sealants and other miscellaneous applications. The demand for such work increased and in 1979 LRS purchased its own SEM. The technical improvements in this type of instrument led to its displacing the TEM for the Division's work. The TEM was mothballed and later disposed of.

The requirements for the characterisation of coal for the slagging gasifier development programme extended the LRS interest in optical microscopy. A photometric microscope was supplemented in 1985 by an image analysis system, used initially for assessing coal maturity and char strength. With the increasing rate of natural gas discoveries and the decline in the SNG programme the techniques were redeployed in characterising rocks in support of exploration projects.

In 1963, the technique of mass spectrometry was introduced by the Basic Research Group to provide an alternative rapid method for gas analysis. Because of its obvious potential for wider application in organic analyses and the policy of centralising specialised analytical techniques, the nucleus of expertise and the instruments were transferred to the Analytical Division in 1968. Application of this technique developed rapidly and in 1975 a modern high resolution instrument with associated data system was purchased. This instrument was used for the qualitative and quantitative analysis of oil fractions, coal tars, soots, fungicides, organic pollutants, sealants, coatings and effluents. Subsequently, in 1985 a further more advanced instrument was purchased.

Gas Chromatography

To return to the other main stream of development, the early 1950s were notable for the introduction of gas chromatographic analysis. Conventional gas analysis had been refined virtually to its limits of convenience and accuracy, and following the demonstration of chromatography as a viable technique outside the Industry (92) attempts were made to build a chromatograph at LRS.

Shortly afterwards the first commercial instrument was purchased and the technique took off over the next five years, with the development of methods for the analysis of town gas, refinery gas, odorant and benzoles, establishing the Gas Industry as leaders in the field (93). A very important aspect of the growth of chromatography at LRS was the initiative taken in "selling" the technique to the Industry at large. Contact with Regional laboratories was firmly established and paved the way for the much wider liaison that was to continue. History was made with the small informal symposium on chromatography in 1963 which was probably the first time that analysts throughout the Industry met together on common ground.

Chromatographic procedures were being introduced also into gas analysis associated with catalyst evaluation in laboratory rigs and on pilot plant. Herein lay the origins of the Plant Analysis Section formed in 1973 to provide an analytical service to SNG plants, especially during commissioning, both at home and abroad if required.

Over the years gas chromatography was refined by improvements to columns, packings, and detectors and in 1966 LRS undertook the first analysis of North Sea Gas on behalf of the Gas Council (94). Yet another important application was the measurement of traces of sulphur compounds in gas leading to the development of the simple and inexpensive LRS odorant chromatograph (95,96). This was followed in 1970 by the publication of the first analysis of indigenous sulphur compounds in North Sea gases (97), the development of an automatic odorant chromatograph, and a method for monitoring odorant addition (98).

Other developments in chromatography included basic studies of high speed chromatography, which led to developments elsewhere in the Industry; the establishment of "fingerprint" techniques for rapid matching of condensates in mains with possible sources; and the introduction of an automatic chromatograph for light oil fraction analysis.

Liquid-liquid chromatographic separation was first used for the analysis of phenols in effluents (99). However, later separation at high pressure was exploited as high performance liquid chromatography (HPLC). This was identified as a technique of great potential, particularly for the analysis of heavy hydrocarbons and trace levels of environmentally significant materials, and by 1990 five instruments were in operation at LRS.

Materials Work

The build-up of comprehensive facilities for inorganic analysis in the 1960s led to an increasing involvement with operational problems and in particular those associated with metallurgical failures in reforming plant. At this time there was close co-operation with the Engineering Research Group located at Fulham. When the Group moved to Newcastle to become the Engineering Research Station it was obvious that a metallurgist was needed within the Analytical Division at LRS if the best use was to be made of the facilities available. The close liaison and understanding between the metallurgist and the analyst justified this bringing together of what at first sight might be considered two unrelated disciplines.

Although the level of trouble shooting work declined as conversion to natural gas was implemented, the experience gained was channelled into longer term research into materials required for the gas making processes being developed for the future. This research concentrated initially on the solution of materials problems associated with oil and coal hydrogenation plant, and with the Westfield Slagging Gasifier.

The principal characteristics of heavy oil and coal gasification systems were that the reaction environments were extremely corrosive to conventional materials of construction. It was clear from previous work in the petroleum industry that none of these materials could withstand the combination of H_2S, HCl and carburising conditions. Accordingly a number of refractory metals such as molybdenum, niobium tungsten and cobalt, and iron-based alloys containing these elements, were tested in high temperature autoclaves and found to be resistant. This work was backed up by an extensive programme of University sponsorship, and collaboration with the CEGB, National Coal Board, and Firth Brown Ltd. Although none of these alloys went into production the results gave support to the "Gettering Theory" of oxidation resistant alloys, developed by F Starr of LRS and Professor Stafford of Newcastle Polytechnic.

With respect to the Westfield slagging gasifier one of the main issues investigated was possible attack on the refractories of construction by molten slag. In the event it did not prove to be a serious problem, but an off-shoot was an innovation developed in the test procedures whereby the slag was heated by making use of its own electrical resistance. This was a vastly simpler and cheaper technique than that of using an oxy-gas burner which had been employed by other investigators hitherto. It also had the advantage that reducing conditions in the slag pool could be maintained. Exceedingly high temperatures could be produced, so much so that on the first trial of this technique the brickwork of the test rig melted and the molten slag poured out - much to the consternation of the Chairman of the LRS Safety Committee.

Another collaborative undertaking at this time was concerned with improving the quality of the slag tap at the base of the slagging gasifier. This was a large water-cooled copper casting through which molten slag was intermittently discharged. In addition to British Gas personnel, the research involved British Steel (Rotherham) and Ogden and Lawson (Workington) which was one of the few copper foundries in the UK capable of producing such a casting. The outcome was a documented casting procedure designed to ensure that slag taps of high integrity could be produced. At the same time, in collaboration with ASEA of Sweden an alternative technique of using powder metallurgy was explored for producing the slag tap. Sadly, however, the work on the tap came to a halt in 1986 with the decision to curtail the SNG programme.

In the following years up to the closure of the Station the efforts of the Materials Section were concerned with research on the materials and engineering aspects of advanced gas turbines (156), and a novel internal combustion engine. The gas turbine work led to a successful European-wide collaborative programme to develop an advanced high temperature heat exchanger, working at metal temperatures above 110°C. Here, work was in hand to explore the application of a life prediction device, developed and patented by LRS in the early 1980s.

Environmental Studies

An important function that developed in the Analytical Division was support to the environmental programme (100). The necessary analytical and biological expertise was acquired and developed for the purpose of monitoring and assessing industrial activities, particularly with respect to exploration activities both offshore and on the mainland.

By 1980 the work had grown sufficiently in size and importance to warrant the formation of the Environmental Studies Group within the Analytical Division. This Group worked, where appropriate, with the Biological Sciences Group to develop and service a wide-ranging environmental programme which, later, also embraced the subject of Occupational Hygiene.

One of the largest areas of work in this topic was that carried out on environmental monitoring and control. This covered a wide range of activities, including air emissions, water quality and treatment, and contaminated land and consultancy. This work was vitally important in ensuring that the Company's legal obligations were met and its image as an environmentally responsible industry was maintained at a time when environmental issues were becoming more widely understood and publicised, and regulatory authorities were becoming more rigorous in their interpretation of increasingly onerous legislation.

The air emissions programme was developed from initial work carried out to demonstrate the low emission characteristics of the British Gas/Lurgi Slagging Gasifier. The technology developed was then employed to monitor emissions around all the Company's operational sites. The data gathered formed the basis for both process improvements and for the environmental assessment submissions to Her Majesty's Inspectorate of Pollution (HMIP) that were required for authorisation under the provisions of the Environmental Protection Act. In addition modelling techniques, developed in house, were used extensively to predict the dispersion of gases emitted by operational processes. This permitted both the prediction of environmental impacts of various plants and the effective design and control of features such as vent stacks.

Pipeline operations can be the cause of both depletion and pollution of surface and groundwater and this occasionally gives rise to complaints from landowners regarding the effects upon their local water supplies. It became routine practice to carry out surveys before, during and after pipelining to ensure that water quality was not affected.

British Gas in 1985 had two wholly owned offshore production complexes, at Morecambe and Rough. From the mid-1980s seabed surveys were carried out around these platforms to determine the extent of any contamination produced by drilling activities, and to assess the effect, if any, upon the seabed fauna. This work enabled the Company to demonstrate that its offshore activities had minimal impact on the environment. The publication of the results of the surveys at Morecambe had useful public relations value as one of the few examples of such work in the public domain, and it was hoped that it would reinforce the Company's future applications for licences.

Contaminated sites were a legacy from the operation of traditional gasworks over a period of more than one hundred and fifty years. The soil on them frequently contained organic and inorganic compounds that would often make development of the land difficult under the environmental restrictions that were currently in force. A substantial programme was therefore put in hand to minimise their pollution potential and to identify methods to improve the options for development. The work included the development of predictive risk assessment methods, improved site survey technology, soil clean-up and decontamination technology, and assessment of the scope for site revegetation and rehabilitation. The revegetation techniques also had important applications on working sites, and were valuable in soil stabilisation of earth banks on several holder stations.

When the Westfield Development Centre was set up to evaluate the potential of the British Gas/Lurgi Slagging Gasifier it became apparent that there would be a need to demonstrate that the effluent produced from the process could be treated for disposal in a satisfactory way. In 1980, picking up the threads of earlier work on effluent treatment, LRS initiated a programme of work which included a proposal for the construction of a demonstration effluent treatment plant at Westfield. In the event the programme developed as a joint effort with MRS and Westfield staff. When the pilot plant was established at Westfield, and under the control of local staff, the LRS role in the project became largely one of conducting laboratory studies of subsidiary techniques such as catalytic wet air oxidation, reverse osmosis, and ozone treatment activated with ultra violet light (ozone/UV).

Effluent control technology, developed in support of the slagging Gasifier, was extended to meet the requirements of other parts of the Companies activities. For instance, ozone/UV was evaluated and used as a method for removing traces of amine present in production water brought ashore from the Amethyst field. Processes for the treatment of gasholder water and groundwater from contaminated sites were also considered to be likely to form useful spin-off from the SNG programme.

For the environmental programme to meet its objectives effectively it was essential that it was based upon a thorough knowledge of environmental issues and legislation. For that reason, over many years, a consultancy function was maintained. It ensured, by attendance at seminars, by membership of committees and by constant survey of the literature, that the programme was based upon the latest appreciations of environmental developments. The resulting information base permitted the production of timely briefing notes for the industry on topical environmental issues.

Beginning in the seventies, when the need developed for frequent assessments of the levels of asbestos in workplace atmospheres, the Station made an important contribution in the field of occupational hygiene. This was initially concerned mainly with the measurement of chemical hazards in the workplace but was extended in time to encompass thermal comfort studies and noise measurements. Starting principally as a laboratory based exercise, the work soon took the hygienists to a wide variety of operational sites, including offshore platforms. The increasing emphasis on safety procedures involved the Occupational Hygiene Unit in providing training for management, and also resulted in its close involvement with the formulation of the implementation procedure for the Control of Substances Hazardous to Health Regulations.

Biological Sciences

With the demise of the effluent work in the late 1960s the Biological Section turned elsewhere to find that there were plenty of problems within the Industry requiring the assistance of the biologist. Sulphate-reducing bacteria had been recognised for many years as the source of hydrogen sulphide in the gas leaving gas holders, and LRS extended these studies to include the anticipation of potential difficulties from these organisms in salt cavity and exploration operations. Other studies included the prevention of biological growths in cooling systems and sea water outfalls; the investigation of possible microbiological deterioration of pipe wrappings and coatings buried in soil; and an on-going review of hydrocarbon production from biomass (in this context, crops grown specifically for conversion to fuel) and from domestic wastes (161,70).

A particularly successful study was of the adverse effects of the underground leakage of natural gas on urban trees and other vegetation. Here, the depletion of oxygen in soil, by various mechanisms, could lead to distress and even death of the vegetation supported by the contaminated soil. The problem was shown to be not as extensive as first feared, fears that were stoked by sensational and mostly inaccurate accounts by the media. Indeed, a positive outcome was the production by LRS of a guide whereby signs of distress in vegetation could be used by Regional staff as early indications of underground gas leaks.

By 1980 the Biological Sciences Group, as the expanded team was now called, was studying the problem of the bacterial contamination of the Stretford Process, which was first reported at a plant in Chicago. Over a period of some years strategies were developed for dealing with the thiobacilli and heterotrophic bacteria that were the cause of the operating problems which were found to be endemic in all Stretford plants treating non-coke oven gases. The use of selected biocides and modified operating conditions overcame the difficulties, and, with the help of the Maths and Computing Division, the diagnosis of the problem and recommendations for its solution were incorporated in an expert system called SAMSON which was one of the first of such systems to deal with industrial processes.

By 1984 the Group was expanding into the developing science of biotechnology, in particular with the study of biosensors that used enzymic activity for the detection and measurement of specific chemical substances. There was a need in the Industry at this time for an instrument that could be used easily by district staff to measure monoethylene glycol (MEG) in gas, and hence to assess the effectiveness of gas conditioning operations. In December 1984 bacteria capable of oxidising MEG were isolated from soil and this marked the start of the MEG biosensor project. After successful development work at LRS, engineers from OLIC joined in the project from 1986 onwards with the result that, following extensive field trials, fourteen instruments were manufactured and delivered in 1991 to all Regions (162,163).

The joint development of the Wytch Farm oil field in the mid-seventies by British Gas and BP, in a highly sensitive area of the Dorset countryside, soon involved LRS in regular monitoring activities to ensure that the operations had a minimum impact on the local environment. Staff of the Biological Sciences and Environmental Studies Groups were involved in a series of monthly visits to the site, which continued, with increasing scope, until, on Government insistence, British Gas was divested of its oil interests (157).

The experience and expertise gained by LRS in this exercise was unique, and was extended in 1985 to the off-shore monitoring of the Morecambe Bay and Rough gas fields, referred to in the previous section. This enabled baseline information to be obtained on the effect on the marine environment of British Gas off-shore activities (160), and led later to LRS scientists working in Gabon, Ecuador, Tunisia, and Bulgaria.

Other work off-shore was concerned with the study of marine fouling of submerged structures. Such fouling could become extensive and could dangerously increase the mechanical loading of structural members and their resistance to underwater currents and tidal flow. With the collaboration of Exploration and Production Department a testing facility was set up on the Methane Progress - one of the early LNG tankers which, in the mid-eighties, was 'mothballed' in Falmouth Harbour. Later this facility was superseded by a purpose built pontoon called the "Veliger". Regular monitoring of this pontoon, together with numerous visits to offshore structures to examine marine fouling and to bring back smelly samples for study in the laboratory, enabled the Biological Sciences Group to learn much of the ecology of such fouling and to make recommendations for its amelioration.

Ecological work on old gasworks sites at Redheugh and Mill Hill successfully demonstrated that such sites, with the aid of imported sewage sludge, could be readily re-vegetated. Unfortunately, the long-term possibilities of this work were halted (much to the disgust of the staff involved) when the Mill Hill experiment was flattened to make way for a pipe store. However, the experience gained in such work led to the formulation of a contaminated land programme, a description of which was given to the IGU meeting in 1991 (158, 165).

Further pioneering work was carried out on the reinstatement of pipelines crossing sites of special scientific interest, which could not always be avoided. Important work was carried out on the reinstatement of the salt marsh at Walney Island which was crossed by a high pressure pipeline from the Morecambe Bay field. This work proved successful despite the problems caused by two successive summers of drought (159). Later, in connection with pipelaying operations in the New Forest, techniques were devised to restore heathland to its original condition and thus avoid it becoming a swathe of grassland. The result of the experience gained with this and subsequent pipeline projects was the production, in association with the University of Liverpool, of a handbook of techniques for heathland restoration (164).

The biological work undertaken at LRS over a period of almost 40 years resulted in many pioneering studies which placed it uniquely, in the UK, in the forefront of industrial biology.

2.10 Operations Division

In many respects this Division could be regarded as the natural successor to the original Fulham Research Laboratory, in that it was principally concerned with aspects of the production and treatment of natural gas and activities which stem from this interest. It was more akin to the other three Research Stations in that it was directly aligned with these main activities of British Gas, together with exploration, storage, and the chemical and chemical engineering aspects of distribution.

Gas Making Processes

Throughout the period from the early fifties to the mid-sixties work was undertaken on a variety of possible gas making processes. The broad aim was to produce gas of acceptable quality and at an acceptable price from feedstocks other than the coals used for carbonisation which were becoming increasingly expensive.

At LRS the emphasis was on low pressure processes, leaving the Midlands Research Station to concentrate on the high pressure end. The low pressure option had to be investigated but with hindsight the prospects were very remote. Following on from the partial combustion of gas oil previously described, Maccormac investigated a cyclic thermal cracker using an alumina pebble-bed heater at Stratford, and then moved on to the experimental Rummel Double-Shaft Slag-Bath Gasifier at Bromley (104).
Neither of these ventures came to commercial fruition. They were overtaken first by cyclic oil gasification (105) and then by continuous catalytic gasification of light oils. This led the Industry into an extensive phase of plant construction using imported technology. It was therefore decided that, during the commissioning of these new reforming plants, LRS should provide a suitably qualified team to assist the contractors' engineers and thus to gain knowledge of the technology and experience in plant operation. This team did invaluable work during the reforming era; it afterwards provided many people who were to hold responsible positions in the SNG field.

An ancillary problem encountered during this period and arising out of the new gas making processes was that of nickel carbonyl formation (106). Contamination of product gas with as little as 0.01 ppm of nickel carbonyl was found significantly to affect combustion of some gases; copious deposition of carbon occurred with consequent extinguishing of some sensitive burners, maloperation of thermostats etc. The problem was encountered first and most dramatically in Scotland (107) when gas from the Westfield Lurgi coal gasification plant was first distributed. Smaller outbreaks of customer service problems were subsequently encountered in several areas; they were found to arise from a variety of instances of possible nickel carbonyl formation, e.g from nickel bearing catalysts, and from trace amounts of nickel in newly commissioned ductile iron mains (108).

LRS contributed largely to the laboratory investigation of the conditions under which this troublesome trace impurity could be formed. It thus became possible to predict likely trouble spots and take preventative measures.

In the continuous catalytic reforming process, protection of the catalyst required pre-desulphurisation of the feedstock so that the product gas was virtually free from hydrogen sulphide. Thus hydrogen sulphide removal, a significant problem in the coal carbonisation era, disappeared but was replaced by the necessity to remove carbon dioxide in order to obtain a gas of acceptable combustion characteristics.

Acid Gas Removal

Work on carbon dioxide removal processes was initiated at Fulham in 1958, in connection with the plan to detoxify carburetted water gas (31). A medium pressure (c20 bar) pilot plant was built later at LRS to study the processes for carbon dioxide removal employed in association with continuous reforming. The objective was to look at improved reagents and column packings offering the prospect of reduction in plant size and economy in the energy required for the regeneration of carbonated solutions.

In the event the contractors to the Industry included licensed processes as part of the reforming plant package and there was no opportunity for the carbon dioxide removal per se. So the pilot plant was used to investigate the computer control of a process plant (109).

As a result of the publication of this work the American licensor of the carbon dioxide removal process used widely throughout British Gas became aware of the existence of the Fulham pilot plant and realised that it was a unique facility for comparing mass transfer data on a range of column packings. Work for this licensor was carried out over a period of years ensuring that relevant expertise was kept alive in the Station.

With the renewed interest in SNG and particularly the conversion of town gas plants on seven works to peak load SNG production, the value of this contract work to British Gas was realised. Production of a compatible SNG requires a higher degree of CO_2 removal than for town gas production and the data obtained during the contract enabled the existing units to be uprated.

Further contract pilot plant studies on the performance of packings and activated hot potash solutions were carried out for Union Carbide and UOP who acquired the diethanolamine activated "Benfield" process from the original developers, Benson and Field.

The Station's own research on the chemistry of amine activators led it to develop and patent an improved amine activator system for the Hot Potash process for CO_2 removal which was called "LRS10". Following extensive laboratory research, pilot plant studies and field trials at the Plymouth and Granton SNG Plants the process was released for commercial exploitation by ICS (later Global Gas) in 1988. Later, about a dozen plants were retrofitted with LRS10 worldwide. All reported improved performance, and the Division provided technical support and development work for Global Gas and their licensees and plant operators.

From 1984/5 the Station took over responsibility from British Gas NW for the BG Stretford Process for H_2S removal. This covered technical support for commercial exploitation and development work on the chemistry and equipment aspects. Advances were made in the process chemistry and the provision of a suite of programs for plant design. Subsequently, development work focussed on a new self-cleaning gas/liquid contacting device to improve reliability and reduce costs.

As part of the SNG programme, research and development work was extended to physical and amine solvents for acid gas removal. The work on amines covered the physico-chemical mechanisms, thermodynamics, kinetics and screening studies for new amine solvents. A second pilot plant was assembled (from units acquired from the Kilmarnock gas making plant) and used to investigate the performance of the "Amine Guard" process using high concentrations of monoethanolamine to remove CO_2 for peak load SNG plants. This allowed the capacity of the process to be doubled without causing unacceptable corrosion rates.

Similar studies were carried out on a range of physical solvents including the pilot plant performance study of the Selexol Process for bulk CO_2 removal. Experimental data obtained from this work formed the basis for an accurate mass transfer model which is essential for reliable absorber column sizing and performance prediction in acid gas removal processes. New solvents with improved selectivity for H_2S removal were identified and patented but were not developed for full scale operations.

Most of the physico-chemical data developed for gas treating processes were incorporated into computer programs. Properties for physical solvent systems were in one called GASVLE, and those for aqueous systems in another known as WATVLE. Computer models of the main stages in gas treating processes were developed and incorporated into the flowsheeting program SWAN for process and equipment design. All programs were available to British Gas, and both of these areas of work were applied to natural gas production.

Water Treatment

The Division also became involved in water purification and effluent treatment processes, and what was then (1985) a new approach called catalytic wet air oxidation (CWAO) was tested in association with Osaka Gas, as part of the programme on the treatment of effluent from the slagging gasifier, and found to be highly effective. The process was found to be able to remove all the oxidisable impurities in one relatively simple process step with no secondary effluents. Research on this method later focussed on better materials of construction to reduce equipment costs.

Natural gas production also often results in the co-production of large volumes of contaminated water at the reception terminal which has to be treated before it can be rejected to sea. Unless this can be done the enormous cost savings associated with unmanned offshore platforms cannot be realised. Research into ozone treatment activated with ultraviolet light led to a very cost effective method of treatment which was installed at the Easington reception terminal.

Liquefied Natural Gas (LNG)

The option to import LNG as part of a future strategic gas supply plan focussed attention on how best to operate in a market where several LNG supplies of considerably different composition were available. Studies were undertaken in association with the University of Strathclyde on the development of a dynamic computer process model for an advanced design of LNG reception terminal that would be able to operate with a wide range of feedstock compositions whilst maintaining a constant output gas quality.

Narural Gas: Properties and Treatment

Following Ministerial approval of the scheme to import LNG from Algeria in 1961, work commenced on the Canvey/Leeds backbone main, the first phase of what was to become the National Transmission System.

LRS was asked to consider any problems likely to arise from the fact that the pre-commissioning hydraulic testing of the pipeline would leave surplus water which could not be removed by the swabbing pigs. The principal potential problem was that of methane hydrate formation. Unless preventative measures were taken the formation, transport and deposition of this solid interstitial compound of hydrocarbon and water could lead to malfunction of valves and control equipment or even blockage of the main (112). Laboratory work was undertaken in order to demonstrate the conditions under which hydrate formation could occur and to provide some information on its properties (113).

The use of methanol swabbing to remove water and to lower hydrate formation temperature was evolved. After extensive field trials the required conditions under which this swabbing should be carried out and the criteria by which the success of the operation could be assessed were embodied in a Code of Practice which was applied throughout the transmission grid as each new length of pipe was commissioned. The year after the LNG importation commenced, natural gas was discovered in the Southern North Sea. The Gas Council, as a partner in consortia carrying out exploration, had access to certain drilling platforms. By attending production tests LRS staff sampled gas and condensate from the well head and acquired data on their composition. This service was offered free of charge to all producers.

From this information it was possible to predict the phase behaviour to be expected if a gas was admitted to the transmission network and underwent successive pressure reduction. Some of these early calculations were approximate by comparison with what was later possible. The extensive work carried out on thermodynamic properties by the Physics Division is referred to later. Even at the early stage it was possible to foresee problems with water and hydrocarbon deposition, unless the properties of the gas to be purchased were very carefully specified (114). The specification dictated the extent to which the gas had to be processed by the producers prior to reception at the Gas Council terminals.

Although LRS had no direct input to the design of the treatment equipment, staff were frequently called upon to assist in solving problems, and provided all the technical service required by the Production and Supply Division in commissioning the Easington and Bacton terminals.

Subsequently Plant Operations (P&S) acquired chemical staff who were given responsibility for chemical control and analysis at terminals. LRS provided an advisory service that could act in a back-up role if a particular problem was beyond the resources of the terminal staff.

Odorisation of Gas

An area of work related to natural gas properties is that of odorisation. British Gas is required to ensure that all gas transmitted and distributed has a distinctive odour. The decision was taken at the outset of natural gas reception to odorise at the terminals to minimise the number of odour injection sites. Throughout the "reformed gas" era, the odorant tetrahydrothiophen (THT) had been used almost without exception by all Regions, since this compound was found to impart an odour not too far removed in character from that of the earlier towns gas manufactured from coal. However, when THT was added to natural gas the odour was modified in such a way that it would not have provided the necessary warning of the presence of leaking gas (116).

Furthermore, when the Leman Bank field was produced the gas contained some few parts per million of various organic sulphur compounds, which imparted a distinctive odour (98,116). Thus a considerable programme of laboratory work developed with the object of prescribing an odorant which, whilst matching the odour of Leman Bank gas, could be added to natural gas produced from all sources. Such a product, Odorant BE, was eventually formulated, and was used to odorise all natural gas distributed in Great Britain (117).

Support to Exploration Activities

Although the start of LRS involvement in support of exploration for natural gas must date from the commencement of activity in the Southern North Sea in 1965, it is necessary to go back to about 1960-62 in order to explain how the Station first gained experience in geological core and fluid testing. At that time considerable interest was being shown in the possibility of storing large volumes of gas underground by displacing water from geological sandstone anticlines.

Two likely structures were located in Southern England, at Chilcomb (near Winchester) and Sarsden (Stow-in-the Wold). In order to assess the potential capacity of such aquifers and the likely movement of fluids (gas and water) in the sandstone during gas injection and withdrawal, information was required by the geologists on the properties of samples obtained by coring during exploratory drilling. The necessary equipment was obtained by LRS and considerable experience on core testing was acquired (166). Neither of these locations was developed for storage but the work put the Station in a very good position to offer a similar service to the Exploration Department when hydrocarbons were located in the North Sea.

The volume of this work increased in line with exploration activity and the Station built, and later expanded, a special Core Store with associated testing facilities, and a Petroleum Store. Cores and hydrocarbon liquid samples could thus be accepted into safe storage, and made available at any time for geological examination and analysis. It was able to carry out a very comprehensive range of tests at costs which compared favourably with those of specialist laboratories offering a contract service (118,119). Thus, LRS provided facilities for the efficient, safe and controlled storage of all British Gas geological core materials. It offered technical service work in support of exploration and production activities in conventional and special core analysis, drilling fluids and cement, reservoir fluid studies, and geochemical and sedimentology studies. There were also considerable core-flooding research facilities. When activities at Fulham came to an end research work was being performed on ways of improving hydrocarbon recovery from gas-condensate reservoirs (167). This experimental work was part of an overall programme on condensate reservoir studies. It provided data in support of a numerical study where a compositional simulator, CONDOR, was being developed. Research work was also being conducted in predicting reservoir fluid behaviour, seismic, and drilling fluid studies.

Technical Service work in conventional core analysis provided the petroleum engineer with rapid response measurements of rock properties such as, porosity, permeability and grain density (166). These were measured on core plugs sampled at one foot intervals and were used to assess optimum perforation depths and other details of well completion. The samples were cleaned by conventional Soxhlet extraction and then dried in an oven at 90°C. Special drying techniques were used on cores which contained sensitive clay materials. Measurements of natural core gamma radiation were also made on the entire sixty foot length of core and were used by the petroleum engineer to correlate with data from downhole wireline logs.

Special core analysis on geological core samples expanded considerably over the years and included relative permeability, capillary pressure and pore size distribution, and electrical resistivity measurements. The data were used to provide more detailed information on reservoir rocks. Relative permeability data, which relate the relative flow rates of oil, gas and water to fluid saturation in the core, were used to determine reservoir performance and assess the efficiency of waterflooding reservoirs. Capillary pressure data were used to identify the oil/water and gas/oil contact so that injection and/or production wells were drilled at the appropriate position. Initial information on the reservoir was obtained on wireline logs, hence accurate interpretation of these data was important when assessing reservoir properties. Electrical resistivity measurements at both ambient and simulated reservoir pressures were used to calibrate these logs.

Studies on drilling fluids and cement were included in the Technical Service programme for 1988. The emphasis of the work in the drilling fluids laboratory was to ensure that muds and cements were suitable for operating in a wide range of conditions and that they met both technical and environmental requirements. Evaluation of tendered drilling fluid systems and analyses of field samples during operations were performed to optimise drilling efficiency and avoid mud related drilling problems. Investigations of additives and novel drilling fluid systems were carried out to validate the integrity of products and their performance.

An understanding of the pressure, volume and temperature (PVT) related properties of reservoir fluids is vital when considering exploitation of hydrocarbon reserves. The detailed information that was required for this type of work was provided by the Reservoir Fluid Studies group at LRS.

A complete service, which included sampling at either off-shore or on-shore sites, standard PVT study, hydrate experiments, separator modelling and theoretical studies was provided by the PVT laboratory. All types of fluids could be studied, from hot, lean and sour gases to rich, waxy condensates and black oils. Reservoir conditions could be reproduced to a maximum pressure of 10,000 psia and 200°C or 17,000 psia and 175°C.

The expansion characteristics of a fluid were studied using a PVT cell, and experiments performed to model the depletion of gas condensate or oil reservoirs. Viscosity of fluids at reservoir conditions was determined with a capillary flow viscometer. The composition of reservoir fluids was determined by chromatography and characterisation of crude petroleum carried out by vacuum distillation. Relative molecular mass of the fractions was determined by cryoscopy.

In geochemistry, technical service work on maturity and source rock evaluation (SRE) and sedimentological and diagenetic studies provided information which helped in determining the likelihood of source rocks being present and whether or not they generated hydrocarbons. Basin modelling gave information on whether hydrocarbon generation occurred after traps had been formed. Should hydrocarbon generation predate trap formation, then there is no prospect of any hydrocarbon reservoirs in the area being found. Sedimentology and diagenetic studies were performed to produce regional evaluations of reservoir quality.

Research work in exploration related topics was being carried out at LRS in the areas of improved oil recovery (IOR), drilling fluids, seismic studies, and reservoir fluid behaviour. The earliest work was that of improved oil recovery; this dated back to the days when British Gas operated the Wytch Farm field (168). LRS became involved with long term research when a decision was taken to use chemicals as a means of improving recovery. Screening of chemicals began as a preliminary to performing chemical flooding in reservoir rock samples.

This work was, however, brought to a sudden end when the government began divesting BG's oil interests. Then, expertise and equipment became available for other work. At a meeting of the Advisory Committee on Enhanced Oil Recovery Research (ACEORR) in the late seventies, gas-condensate reservoirs were identified as potential future source of gas supplies from the UK Continental Shelf. Very little was known about these types of reservoirs although many were discovered overseas, but in the hostile environment of the North Sea exploitation of such wells was made more difficult.

As a result, Exploration & Production Department (E&P) and LRS set-up, in 1981/82, a research programme based on theoretical and experimental gas-condensate reservoir studies. The aim of the project was for LRS to provide E&P with a 3-dimensional compositional reservoir simulator. The unique combination of laboratory and computer simulation studies enabled LRS to develop a computer simulator, CONDOR, that accurately predicted reserves, production rates and compositions of the liquid and gas obtained from gas-condensate reservoirs. These predictions were used both in connection with gas purchase negotiations and in assessing development schemes where BG subsidiaries were partners and/or operators.

Gas condensate reservoirs fall somewhere between a gas and an oil reservoir and producing these to obtain maximum economic benefit is not easy. Depletion strategies which apply to oil and gas reservoirs do not apply to gas-condensate reservoirs. If, for example, condensate fields are produced by allowing the pressure of the reservoir to decline, as with gas reservoirs then, at conditions below the dew pressure, liquid is condensed and remains trapped in the rock formation with the consequent loss of liquid sales. Furthermore, the liquid quite often accumulates close to producing wells causing reduced gas production. This in some cases can kill the well. The research programme was aimed at understanding condensate fluid flow in porous media and at improving hydrocarbon recovery.

Computer simulation is the principal tool for managing oil and gas reservoirs and optimising recoveries. CONDOR, mentioned again later in the section on Maths and Computing, was the first compositional simulator that could simulate all the important physical phenomena that affected the production and productivity of condensate reservoirs (169). It contained a number of unique features established by the experimental programme, and was being used to simulate reservoirs in the North Sea and fields in other parts of the world such as in the Commonwealth of Independent States (formerly the Soviet Union).

CONDOR was a fully compositional reservoir simulator based on finite difference equations. With some 180,000 lines of FORTRAN code, it was in 1992 one of the largest computer models ever written for British Gas (170). It had the facility to model reservoirs of simple or complex composition and provided a valuable tool in planning development programmes for condensate reservoirs.

One of the novel features of CONDOR was its ability to simulate gravity segregation and the effects of interfacial tension on condensate recovery (170). Gravity segregation is a phenomenon that results in the variation of the composition of the hydrocarbons with depth, and if this is not taken into account when simulating the reservoir it can lead to 30% error in estimating the amount of recoverable hydrocarbons (172).

Experimental studies carried out on fluid flow in porous media provided new methods for improving liquid recovery and maximising hydrocarbon from gas condensate fields. The key to improved liquid recovery lies in the factors that determine the relative permeabilities of gas and condensate phases in the porous media. Relative permeability (171) is an empirical parameter and its value is strongly dependent on levels of saturation in the porous media and on interfacial tension of the fluid phases; this in turn is affected by pressure, temperature and the composition of the reservoir fluid.

Interfacial tension (IFT) is probably the most important factor affecting fluid flow and distribution in the porous media (173,174). The work at LRS showed that there exists a critical IFT value below which there is a significant increase in liquid recovery, At these low IFT values gravitational forces become dominant causing the liquid to drain and flow easily between rock grains. The above observations led to the concept of Low Tension Pressure Maintenance (LTPM) as a strategy to maximise both liquid and gas recovery.

A comprehensive experimental programme was in progress in 1992 which used the CONDOR reservoir simulator to evaluate the viability of the LTPM strategy for North Sea fields. Preliminary experiments showed that in many cases the LTPM method could be superior to the depletion strategies that were currently being used.

Work on advanced seismic techniques, centred around the design of a new seismic shock gun, is referred to in the section on Physics Division.

In the last ten years or so at Fulham LRS considerably expanded its exploration activities from routine technical service to complex long term research, activities which, it was felt as the Station closed, would need to be developed and expanded further elsewhere.

Distribution - Leakage Control

In 1964 the Engineering Group, under John van der Post, was set up on the Fulham site primarily to tackle the engineering problems of transmission and distribution. Initially it became involved in the metallurgical problems of reforming plant that were bedevilling the Industry at the time, but soon picked up the problems of high pressure transmission mains and control equipment, and the potential problems in distribution following conversion to natural gas.

Expansion was rapid and the Group moved to Killingworth to become the Engineering Research Station. When the 'engineers' moved North they left behind at LRS one leakage problem considered to be chemical in nature. This was the shrinkage of rubber joints in mains following conversion to dry gas (i.e. gas in which the Relative Humidity is extremely low).

The introduction of dry gas in place of 'wet' towns gas greatly increased leakage through shrinkage of joint packings previously swollen by constituents of towns gas. With over 70% of joints in the distribution network made with lead and yarn packings which are prone to leakage, some 250,000 find and fix repairs were necessary in 1978. Treatment using water or glycols to re-humidify the gas and re-swell the joint packing had been introduced by 1978 but, through poor application procedures and lack of knowledge of how the techniques worked, they failed to reduce significantly either the number of repairs or their associated leak rates.

So LRS became involved in what developed into a comprehensive programme aimed at controlling the potential leakage problem resulting from the drying out of joints. Initially work concentrated on laboratory investigations of gas conditioning techniques, the most promising being taken into the field where the scientific staff worked closely with Regional engineers in evaluating their effectiveness. Additionally, after 1967, efforts were made to develop processes for the internal sealing of mains in those instances where the joints did not respond to the gas conditioning treatment (177).

This work was complementary to the extensive programme at ERS, where they concentrated on the external repair of individual joints, and pilot scale evaluation of gas conditioning techniques to support the laboratory investigations at LRS. External repairs were a necessity for an emergency situation or where only isolated joints on a particular main required attention.

The work at LRS fell into two phases. Following the first phase, referred to above, the second phase concentrated on reducing costs by introducing lower cost methods requiring a minimum of excavation. These developments centred on the widespread use of anaerobic resin sealants.

Phase 1: Improving Reliability

In 1979 work at LRS established the full potential of systems treatment using monoethylene glycol (MEG) to reduce joint leakage and made it the Industry standard treatment. A long term trial showed that using MEG fogging reduced joint leakage by up to 80%. The effects of variables such as flow rate, temperature, pressure, position of equipment etc. were highlighted in numerous publications (175,176). A definitive work "Gas Conditioning with Monoethylene Glycol (MEG)" (181) was published and more than 2,500 copies issued to Regional staff. Gas conditioning with MEG using LRS guidelines was fully implemented with 2,000 fogging installations in use. Annual savings were estimated to be £13 million from the reduction in lost gas and reduced repair activity.

The need to control MEG concentrations led to the development of on-site analysers, with the objective of replacing methods of collecting samples for laboratory analysis which were labour intensive. The LRS Quantitech and LRS Biosensor (referred to in the section on Biological Sciences) were proven in field trials, and production instruments became available at a cost of around £7,000 each.

An extensive survey of encapsulated joint repairs, organised by members of the LRS team, showed that up to 20% were unsatisfactory, leading to extensive and expensive re-repairs. To overcome this problem the team identified the areas for development and prepared specifications requiring a 50 year life for all repairs. Close co-operation with Bayer (Germany) led to a new range of flexible polyurethane resins and the introduction of an entire new range of highly successful encapsulation repair systems. Failure rates were thus reduced to less than 0.02% p.a., and both the specifications and repair kits were used worldwide.

Gas escaping from broken mains can present a major hazard. Each year approximately 17,000 pipe repair clamps and collars were fitted to repair fractures, and a similar number used to fit service offtakes. Surprisingly, at the outset, these were not manufactured to any universally accepted specification. LRS identified the key problems and introduced new specifications which ensured a 95% probability of a first time fit, and a predicted in-service lifetime of 50 years (D06).

Part of the specification dealt with rubber quality. Research work showed rubber relaxation was a key property and led to the need to re-compress some seals after a period of time. Extensive studies of stress relaxation and its relationship to seal durability resulted in new test methods and a new specification for elastomeric seals used in compression.
The initial response from clamp and rubber manufacturers to the specifications was disappointing. New designs were not introduced until LRS proved the feasibility of the new specification by fabricating new clamps and gaskets. The use of clamps to the new specification was made mandatory by British Gas in 1988, and a full range of re-designed pipe repair clamps was introduced.

The high cost of 'find and fix' repairs, especially on large diameter mains where "man entry" is possible, led to an extensive programme of internal sealing. Repairs were initially restricted to "Wecoseal" which used compressed rubber seals. The durability of the seals was greatly improved following the introduction of the rubber specifications, but the system remained expensive.

LRS utilised their expertise in polyurethane formulation to develop an internal spraying technique which applied high-build, non-slumping coatings (179). Following a series of field trials, ALHCO Ltd acquired a licence to develop the system further for a wide range of pipelining applications. A survey indicated a very extensive additional market for renovation of sewer and slurry pipelines.

Phase 2: Reducing Costs

In 1984 with reliable systems available for most applications the emphasis of work at LRS was shifted to reducing costs. Priority was given to reducing the cost of joint repairs using novel anaerobic resins. Further applications for these materials were identified and developed. In addition, new lining methods for refurbishing vulnerable cast iron mains were also given priority.

Initially, anaerobic resins were expensive, restricting use to low volume applications such as thread locking. By the early 1980s a wide range of low cost anaerobics was available enabling the development of anaerobic joint penetrating sealants (178). These materials were injected into the joint packing where they cured to a rubbery solid in the leakage pathways. LRS prepared a performance specification and associated notes for guidance, ensuring reliable implementation by the industry. External injection of anaerobic sealants accounted in 1989 for nearly 90% of find and fix repairs. With costs only 70% and 40% respectively of those for low and medium pressure encapsulations, annual savings were estimated to be £6-7 million at 1989 prices.

Anaerobic resins were also modified for application to the inside of mains for joint treatment. Up to 140m of live main could be treated from a single excavation by inserting a stiff hose fitted with a combined spray head and joint locater. LRS workers developed improved resins for joints up to 24" in diameter, providing substantial savings as compared to find and fix repairs. A further development with anaerobic resins, which was developed and patented by the LRS team, was the internal sealing of screw jointed steel service pipes inside buildings. Application from a single point was quick, cheap and dealt with all joint leaks. The method superseded the well proven 'fill and drain' method, introduced by LRS in 1976. Anaerobic resins are unaffected by extreme changes in 'ambient' temperature and offered great scope for overseas markets.

For those joints not suitable for repair by anaerobic sealants, and particularly for "special" fittings such as valves and tees, LRS researchers developed "Unicap", a universal muff-less encapsulation. The system used a novel polyurethane resin which on mixing rapidly gels to a putty-like consistency and could readily be trowelled around a leaking joint without the need for specific moulds for each type and size of joint. Savings of up to 50% compared to conventional encapsulation were possible with this technique.

Hose lining systems were introduced to provide leak and fracture resistance to vulnerable cast iron mains. LRS provided technical support to the Regions to overcome initial operational difficulties, and produced notes for guidance and an associated site organiser manual. Quality systems were improved and site problems minimised, allowing reliable implementation of this technique with savings of up to 50% of the costs of replacement. A particular effort was also made to ensure that sound service connections could be made, and a range of specially developed fittings was produced in conjunction with a number of suppliers.

Despite the improvements in techniques and associated cost reductions, and the reduction in lost gas, there was in 1992 still scope for further significant savings. Two major proposals were passed on to ERS. The first was a system for permanent conditioning of joints to eliminate the need for any further MEG treatment. Here, specially modified anaerobic resins were fogged in place of MEG or, alternatively, applied via slugs of foam propelled down the pipe. The second area was in the repair and replacement of service pipes. The development of epoxy lining systems and plastic pipe insertion with annular sealants, under live gas conditions, could eliminate the need for excavation with consequent major savings.

It can be concluded that the LRS Leakage Control Group played a key role in inventing, developing and implementing many of the major advances that reduced repair costs for the Industry from £150,000,000 in the 1970s to £50,000,000 p.a. in 1992. Total savings to the Industry from work at LRS was estimated to be £150,000,000 compared with the cost of work at LRS of less than £10,000,000.

2.11 Mathematics and Computing Division

Computing at LRS...1966-1978

Computing work at the London Research Station began in about 1966. The primary interest at that time was in process control and chemical engineering, with a specific application to computer control of process plant; an Elliott ARCH 1000 computer was being used for on-line control of the carbon dioxide removal pilot plant (109). The computing effort was rapidly expanded with the founding of the Systems Engineering Group and the arrival of an 8K IBM 1130 computer (this occupied a floor space of about 6' x 4') so that by the end of 1967 there were about 15 project staff who were concerned with computing, programming and mathematics.

Systems engineering may be defined as the study of the way in which parts of a process interact and how to co-ordinate these parts in the best possible way. 'Parts of a process' is to be interpreted in the widest possible sense, for example, the components of a mechanical design, the units of a chemical plant or of a gas transmission system, or the departments within an industrial organisation. The emphasis in systems engineering is on the overall performance of the total system although this may entail detailed mathematical modelling of individual system components. The implication is that the study of the total system requires highly developed mathematical and computational techniques.

The early work of the Systems Engineering Group was on the simulation of chemical plant with particular emphasis in looking at the stability of the control system of gas making plant. At this time, of course, the Industry was beginning to build a national high pressure pipework system for the transmission of natural gas recently discovered in the North Sea (building on an embryonic system for transmission of Algerian natural gas arriving at Canvey). This advent of natural gas radically changed the emphasis of the work to the planning and operational needs of transmission and distribution; computing effort was thus extended to the simulation of gas transmission systems, usually referred to as network analysis (124,125).

Distribution and transmission engineers need to be able to predict how pressures and flows in a gas grid vary as the demand pattern changes. The uniqueness and complexity of the British Gas transmission system gave rise to the need for novel developments in network analysis; for example, how adequately and accurately to represent compressors and regulators operating in highly looped or meshed systems.

So, one of the major project areas in the mathematics and computing area in the 1970s became the development and implementation of a whole suite of software for advisory control of the national grid (127). Advisory control, as distinct from closed-loop control, is output from the computer on which the operators and controllers act in order to operate the grid in the most secure and economic manner, rather than this action being taken without manual intervention.

The work progressed to the extent that by 1978 engineers in the Industry had very powerful and efficient network simulation methods at their disposal, and exploitation overseas of the techniques and software was developing. The overseas situation was typically one of simple gas distribution systems becoming more complex and requiring more comprehensive analytical techniques of the type developed for the British system.

The programs developed at that time made good use of the multi-programming abilities of computers, in particular the time-sharing feature of the computers and their capability for demand or interactive working between the user and the computer, as well as the usual batch facilities. These interactive techniques were exploited to give the transmission engineer the ability to converse with the computer in a near-English type of command language. This made for ease of use and drastically reduced learning times for new program users. Again, the data handling methods employed reduced the tedium involved in organising the vast amount of data necessary to represent the dynamic behaviour of large gas grids.

The programs, PAN and PILOT, were the embodiment of many years of careful thought and experience in network analysis. Technically, the algorithms they contained were very robust, essential for representing the special features of the transmission system, and were highly efficient computationally. Both programs were fully documented and supported which made for efficient implementation, training, enhancement and maintenance within the Industry and outside.

The programs in regular use at this time included those that enabled weather forecast evaluation and short term demand prediction (128), together with grid simulation for assessment of security and correction of possible insecurity. There were programs for the most economic scheduling of supplies and other operational techniques, such as maintenance scheduling (129). These and other data handling programs were all being used on a routine basis. There was a continuing programme of activity in enhancing the programs' capabilities and refining the economic criteria they contained. There was significant development of techniques which utilised the on-line grid data, available via the instrumentation and telemetry systems regarding the pressures, flows, valve states, and so on; this gave an automatic picture of the current state of the grid from which the simulation programs predicted ahead in time.

In 1970 the Systems Engineering and Chemical Engineering groups were combined to form the Mathematics and Computing Division, providing many of the features of a scientific and engineering software house for Headquarters in particular, and Regions in general, that is a capability for the development and support of computer programs, consultancy in general computing matters, mathematical modelling and simulation and, where appropriate, provision of computer bureaux facilities.

By about 1970, the IBM 1130 had been extended to its maximum possible size and computer time was being bought out on a series of computer bureaux, principally UCC and SCICON; there were also batch and demand terminal links into the EMGAS Univac 1108 computer. This rather difficult and diffuse period was very satisfactorily resolved in 1973 by the acquisition of a Univac 1106. In the course of time both batch and demand terminals were linked into the LRS computer from Watson House, MRS and other Headquarters' departments. Access was also provided from elsewhere by use of 'dial-up' facilities.

Considerable expertise was built up in the problems associated with data handling. The success of many application areas is dependent on the ease with which data can be stored and retrieved selectively. LRS was active in setting up data base systems for several Headquarters' departments. Generally speaking, the customer is aware that he has a data handling problem and that the computer can assist him, although he is unaware of the exact potential the computer offers. This latter point may limit the specification given by the user to the systems analyst. The approach was, therefore, to get a pilot system working for the user; in the light of experience in its use, he gains an appreciation of what is possible and is then able to give a more comprehensive specification for the next stage of development. Data base techniques were evolving rapidly in the computer industry with special purpose languages becoming available. Recommended procedures and language specifications were the subject of continuing committees, whilst some manufacturers chose to 'go it alone'. This changing situation needed close study and evaluation to ensure that the Industry's interests were best served, that useful recommendations were adopted, and that unconsciously the scope for future flexibility and compatibility was not lost.

Reservoir simulation was another area which received attention in the 1970s. The essential requirement was to be able to forecast the behaviour of hydrocarbon fluids in reservoirs, under different conditions of depletion over a number of years during extraction. The aim was to provide Exploration Department with a range of reservoir models for forecasting problems of gas fields and interpretation of well data (119,130).

From the early days of using a small IBM 1130 through to using large bureaux computers, and finally acquiring the Univac 1106, LRS spent considerable time in organising the tools for the job. This resulted in a strong in-house capability in systems software and followed a policy of not being entirely dependent on the computer manufacturer for systems software support. Some of this expertise was directed internally to selecting and configuring the LRS computer system, maintaining and modifying operational systems software, and so on. This know-how was also exploited on a wider front in assessing the capabilities of new ranges and generations of computers, in particular their scope for scientific and engineering work, interactive facilities and potential for grid control purposes.

In these years a small team was set up for performance measurement work which was deployed under the auspices of Computer Coordination, Economic Planning Division. Performance measurement uses such techniques as hardware monitoring in conjunction with software instrumentation, and is directed towards improving the efficiency of existing installations, effective enhancement of current systems to take on new tasks, and assessing future workload and system development requirements. The team worked for a number of British Gas Regions including Wales (131), North Thames, Eastern and West Midlands.

Development and Change....1978-1993

This then was the state of development of the Maths and Computing Division in 1978. Subsequently, the Division underwent two major reorganisations. In 1978 the London Computing Centre was set up on the Fulham site and more than half the Division was transferred there along with the Univac 1106 computer. The work transferred to LCC was concerned with computer operating systems software and database software and the operation of the 1106 computer. This left at LRS work on transmission and distribution network analysis, grid control software, and reservoir simulation. Then in 1989 work on network analysis and grid control software was transferred to ERS together with over 20 staff positions. Several staff opted to make the move to Newcastle and became key members in a much strengthened Maths & Computing Division at ERS.

Advances in Hardware

After 1978 there was a considerable change in the nature of the computer hardware used by the Division. For a few years after the transfer of the Univac to LCC it continued to be used as the main platform for program development. In the early 1980s a Vax minicomputer was installed at LRS mainly to be used for the support of laboratory work and administration. Later it became a useful system for the Maths & Computing Division, particularly as some of its customers in the Regions also began to use Vax computers for their engineering applications. Vax computers heralded an era where computers became cheap and powerful enough to be dedicated to engineering applications and the engineer no longer was obliged to fight for time on large mainframe systems on which commercial systems took priority.

In the mid 1980s the personal computer arrived and costs were low enough for departments to afford several machines. At first the limited power of the PC restricted its use as a platform for engineering programs. But within a few years through the improvement in PC capabilities these desk top machines became very important, particularly for running network analysis programs. More computationally demanding problems like reservoir simulation were too large for PCs at that time and continued to be developed on mainframes for some years. The advent of the work station made it possible to take these large applications off mainframes and run them on dedicated hardware. In 1991 a small network of Apollo and Hewlett-Packard work stations was installed at LRS for the development of reservoir simulation programs. Another hardware development was in parallel computing systems that promised high computational power at low cost. An Alliant FX 80 with 8 processors was installed at MRS in 1990 and was used to investigate the opportunities for using parallel processing techniques in computational fluid dynamics, reservoir simulation, and other technical applications. The Alliant was later replaced by a Cray Y-L. The traditional mainframe was no longer used and the future of technical computing appeared to be with a mixture of desktop computers and central high performance computers for really large computational problems.

In addition to advances in computer hardware after 1978, there were very significant changes in the way that computers were used. In 1978 the bulk of usage was still in batch mode in which all the data was entered before the program was run. The program ran when computer time was available and the results were returned to the user. The advent of dedicated computers like PCs and workstations promoted the use of interactive computing in which the user enters data on request whilst the program is running. This allows the user to change his strategy in the light of intermediate results, which is particularly useful if there are errors in the data. The use of PCs and workstations also promoted the use of graphics. Program output in the form of large tables of numbers were rapidly replaced by user-friendly graphics which could convey much more information in a single glance.

During the 1980s much more emphasis was placed on the production of software that was reliable and easily maintained (189,190). Programs became larger and more complex and were expected to have a long lifetime. An important step was the adoption of the Fortran 77 standard which enabled large codes to be developed without the need to use non-standard coding features. The Division also adopted methods and standards for program design and testing. It started to use software tools to help it develop and maintain software, and there was standardisation of input and output through library routines. Perhaps the biggest influence of this approach was in the writing of the FALCON network analysis code, referred to later. Code reviews were held and the programmer's individuality was firmly suppressed. This was generally accepted as necessary but there were a few grumbles about review meetings that spent an hour discussing the number of spaces used in comments!

Program Development

In the late 1970s the work for Exploration and Production (E&P) began to bear fruit. A simulation program for gas reservoirs called PROGRESS was released in 1979 and was used extensively by E&P (201). In the early 1980s the start was made on the development of a condensate reservoir simulation program as condensate reservoirs were seen as an important source of gas for the future (182,202). This program had to model the multiphase flow of the condensate fluid. A lot of work was required to model this behaviour and to produce efficient solution techniques for the large system of non-linear equations that resulted. The CONDOR program (referred to in more detail in the Section on Operations Division), was finally released in 1991 and was the most complex program ever to be developed at LRS. It was soon in serious use for simulation of the Karachganak field as British Gas made their successful bid to become operators. In 1992 work was in progress to produce a gathering network program (GANNET) to link with CONDOR.

There was considerable effort on developing computer programs for chemical engineering in British Gas, particularly those relating to the design of plant for gas and oil processing, gas manufacture, utilisation and so on. The flowsheeting program SIGMA was developed for naphtha reforming, and then SNG from oil and coal. Another flowsheeting system called PROFLO was used for gas treatment and LNG. SIGMA and PROFLO were later combined into SWAN which was a fully interactive PC-based system. SWAN was used by engineers throughout British Gas and was able to handle a wide variety of processes. A program called SCRAP was developed to model the steady state behaviour of a coal gasifier.

Network analysis continued to be an important area of work until it was transferred to ERS (184,187). The most significant development was the FALCON program which took over from PAN in the analysis of transmission networks. FALCON had many improvements in mathematical and software techniques and could easily be run on different computer systems. Changes in the programs for distribution networks were less radical but there were considerable improvements in the software quality with the rewriting of codes to use Fortran 77. These improved versions were also given new names so that PILOT became PEGASUS. A co-operative project with ICL led to a version of PEGASUS with a graphical interface to run on Sun work stations. Versions of the codes also appeared on PCs - SNAP for distribution networks, PACE for transmission networks. The improvement in the computing capabilities were by that time so great that it was no longer necessary to produce specific codes. A new development shortly before the transfer of work to ERS was a program that could optimise pressure settings on a distribution network so as to minimise leakage.

Optimisation became an important theme in the programs developed for grid control (185,186,191). OSCAR was developed to minimise the fuel costs of running compressors on the National Transmission System and after several years in use work began on a replacement of OSCAR. The new program called COANTS finally emerged after the transfer in 1991 of work to ERS. Another optimisation program called SOURCEPLAN was written to calculate the best strategy for taking gas from the North Sea suppliers to meet the daily demand. The original version of SOURCEPLAN worked successfully for several years. Problems were encountered with an improved version because the method of optimisation based on linear programming took no account of smoothness so that it was possible for takes from an individual supplier to change dramatically from day to day for no apparent reason. The problem was eventually solved by using quadratic rather than linear programming and this allowed smoothness to be built into the optimisation. A major new project was started in 1985 to build a continuous simulation program for grid control. This program would run continuously and use operational data to calculate the state of the network at any time and then to predict ahead for several hours to warn of any possible problems. The development of this program was completed at ERS.

In the mid 1980s came the announcement by the Japanese of the 5th generation project, the aim of which was to build computers that could take complex decisions in place of skilled humans. This caused tremendous excitement and public concern in the West and caused a boom in work on 'expert systems'. LRS set up an advanced information technology section which worked on expert systems and used exotic languages like Prolog and Lisp (183,188). They developed a few small systems, for example to advise on weed control and controlling bacterial invasion in the Stretford process. But like everyone else they found that the development of larger systems was extremely difficult. So the emphasis of this work moved away from expert systems to new techniques for processing information on the computer. There was a particular interest in the use of hypertext for managing large sets of text with graphics. A particular application was managing the contracts which defined the terms for the supply of gas from the North Sea.

Parallel computing systems started to appear on the market in the late 1980s. These systems were designed to give increasing computer power at low cost so that some of the really complex computing applications could be solved. LRS started to investigate possible applications for these systems in British Gas. The main obstacle to progress in parallel computing is in the development of software that can make effective use of the power available. LRS worked on CFD and reservoir simulation codes to get them to run efficiently on parallel computing systems. The development of hardware and software was very rapid, with the expectation of significant improvements to come in the years to follow. In particular, the growth in computer power with reduction in cost would continue to have a large impact on science and engineering.

Two important applications in stress analysis at LRS in the 1980s were the program SPIRIT, which calculated the stresses in a piping network and checked the design for conformance to IGE TD12, and a program which calculated the effect of stress in salt cavity storage. The salt does not deform elastically - it creeps, so that eventually the cavity will close up. The program was used to check that significant closure did not occur in the designed lifetime of the storage facility.

Computing for Administration

Mention should be made of the increasing requirement for computing in administrative and office systems. This grew to become a significant part of the computer load on the central Vax computers - there were by 1992 two 6410s and an 8530 - and also a high proportion of the support effort in the Computing Section. All the staff in LRS were users of the Company Office System (COS), and one of the 6410s was devoted to the COS system. COS was on everyone's lips in 1990 as staff were trained to become responsible users. A help desk was set up and user meetings were inaugurated. COS had already become indispensable for many staff and it became difficult to imagine life without it. It created its own problems - staff now had to deal with junk electronic mail which threatened to overwhelm allocation of disk storage, and occasionally messages of a personal nature would reach the wrong destination. But it all added to the richness of life at LRS. The R and D Management Information System (R&DMIS) database also started to be an important part of life for senior managers. As they took more responsibility for controlling their own budgets they needed to turn to R&DMIS to find out what was the current state of their project expenditure. R&DMIS was far from user friendly - such refinements were considered too costly for the original development. It was expected that R&DMIS would have an even more important role to play in the future as local management of budgets became more firmly established, it was hoped that the money would be found to make it a pleasure to use rather than a pain.

2.12 Physics Division

The Physics Division was formed as the successor to the Gas Council Basic Research Group which started on the London Research Station site in 1962. The reasons for setting up this group are of some interest. Its origins can be found in the report of the Select Committee on the Nationalised Industries of 1961 (132). Although the Select Committee recognised that Gas Council research put considerable effort into development and technical service, it felt that there was a significant lack of effort in basic scientific research in support of technological developments. As a result of this criticism, the Gas Council decided to set up its own Basic Research Group. The responsibility for establishing this group then devolved on the Council's Scientific Adviser, Sir Charles Ellis. The group was at first based in temporary laboratories at LRS by the good graces of G. U. Hopton, the Director of LRS, whose help in getting the group off the ground was invaluable.

The date of commencement of the group as a living entity was 2nd February 1962. The staff complement on that day comprised the Head of the Basic Research Group, two scientists and a secretary. History repeated itself in that the laboratory was part of a former stables block.

The role of the Basic Research Group came in for considerable discussion in the periods before and after its inception. It was clearly important to establish that its role was not to carry out the kind of pure scientific research which was being carried out by the universities. The most appropriate role was felt to be that defined by Sir Solly Zuckermann in the classification of research activities by his committee (133), in 1961, as "objective basic research". The establishment of criteria for objective basic research was laid down by Dr. J. A. Gray, in his Research Communication GC105, to the Institution in November 1964 (134). Such criteria allowed one to define university research as "pure" basic research where the individual pursues his own lines and intellectual sincerity. "Objective basic research" is, on the other hand, carried out in recognised fields of technological improvement. "It is stimulated by technological needs and relevance to a definite technological objective, is a practical criterion that differentiates objective basic research from pure basic research."

With these guidelines, the areas of research in which the Basic Research Group was involved in its first few years included catalysis for steam reforming of hydrocarbons (135,136), the basic kinetics of non-catalytic hydrocarbon hydrogenation processes, with particular reference to the Gas Recycle Hydrogenator (137,138), physical properties of gas mixtures at high pressure (139), and at high temperatures (140), problems of flame stability (141), explosion phenomena (142,143), analytical mass spectroscopy (144), and energy conversion, with particular reference to fuel cell developments (224). It is worth noting that the tradition of expertise in these areas was maintained throughout the life of the Physics Division, even though the staff of the first few years had moved on to other things.

When Hopton became Research Co-ordinator to the Gas Council in 1966, the appointment of the Head of the Basic Research Group as Director of LRS naturally helped the process of integration of the group into the Station as an administrative whole. Such integration was further facilitated with the completion of both phases of the new building in 1967 and the consequent capability for most of the staff on site to be housed under one roof. Over the next two or three years, the corporate role was emphasised and in a revision of the Station structure in 1969 the Basic Research Group was re-titled the Physics Division, with the continuing responsibility for objective basic research in physics and physical chemistry.

The Physics Division continued to carry on the role of more basic support to a wide range of Areas of Activity in the Research Programme. With the development of particular technical areas after the first implementation of the Research Planning Cycle, there were changes in emphasis which meant that much of the R and D supported work in the Division was devolved to user division support. This was, of course, a natural process in project development and was to be welcomed but at the same time it was recognised that the role of the Division in carrying out research in anticipation of technological developments could be somewhat restricted if such processes went too far. For this reason, it was necessary in 1978/79 to seek approval for an increase in manpower to ensure the extension of the nucleus of R and D supported work in the Division.

In recalling the work of the Physics Division it is instructive to illustrate it in terms of the principal Areas of Activity of the Research Programme so as to give some idea of the wide range of areas supported. The breadth of involvement of the Division represented its contribution to the corporate role of LRS, a role which evolved in the 1960s.

Exploration and Natural Gas Production

In the early 1970s the Physics Division was responsible for generating and critically evaluating the data on gas properties contained in the first volume of the British Gas Data Book (145). This publication was sold worldwide as well as circulated throughout the Industry, and represented an easily-digestible summary of computer program development for physical property data needed in the transmission, treatment, distribution and storage of natural gas. It was followed by a second volume on the properties of Substitute Natural Gas (204). In the late 1970s and 1980s, with the general availability of computers throughout the Industry, further developments in property and process prediction were made available as computer program packages. The revision of, and extension of, Volume 1 as the program GASVLE was then made available, which in turn was enhanced into the process simulation program PROFLO. An accompanying simulation package, NETFLO, provided the means for simulating single and two phase flow in pipe networks.

Standards for gas properties, always of interest, became particularly important in the 1980s. The accurate measurement and prediction of compressibility factors for European natural gases was an important aspect of this process, in which Physics Division expertise combined with that of other European countries within GERG to establish ISO standards (205,206,207,208).

The accurate measurement of calorific value for natural gas was always important, particularly as it was a legal requirement to carry it out to a specified accuracy. The Physics Division provided the only reference calorimeter facility in British Gas, which provided combustion calorimetry to an accuracy of 0.05% in the calibration of standard gas mixtures for field calorimetry. A new design of field combustion calorimeter, the LRS Recording Calorimeter (209), broke the mould of conventional calorimeter design and brought field calorimetry into the electronic age. It was an instrument that was less environmentally sensitive than others that were then commercially available. The revision of the Gas Act in 1986 removed the restriction that measurement of CV should be made with combustion calorimeters and allowed gas chromatography to be used. So the projected expansion in the commercial sale of the LRS Calorimeter was halted.

In the late 1980s the development of new seismic techniques for the exploration of natural gas became an important part of the activities of the Physics Division. Seismic methods which improve data quality and resolution can lead to an increase in the percentage of economic holes drilled and provide considerable cost reduction and business advantage. A seismic technique, for example, which is specifically sensitive to hydrocarbon deposits and not just to sedimentary structure could reduce exploration drilling costs by some 80%.

Development of these techniques was based on a new type of seismic gun designed at LRS for offshore use. This was a gas dynamics device which, fired from the sea surface, produced a shock wave which propagated to the sea bed. There, the wave converted to compressional and shear waves which subsequently propagated into sediment strata and reflected at interfaces. The ability to generate simultaneously compression and shear waves then made it feasible to analyse the reflected waves to detect fluids in the strata, since shear waves will not propagate in fluids. The fully automated, rapid firing, seismic shock gun, developed at LRS, underwent trials at Loch Linnhe, Wraysbury reservoir, Anglesey coastal waters and over an area of known on-shore gas deposits.

Although this was a reasonably well developed technique for fluid deposit detection on-shore, the particular characteristics of the LRS seismic gun allowed the extension of the technique off-shore (210).

SNG Production and Methane Conversion

The Division was in the forefront of catalyst research since the early days of the Basic Research Group, and in the early 1970s it was heavily involved in developing catalysts for SNG production (147). In particular the development of a variant of the CRG (Catalytic Rich Gas) catalyst CRG "H" had considerable advantages for the catalytic gasification of heavier feedstocks such as kerosine and gas oil. Subsequently, a modification of this chromia-containing catalyst was successfully developed as a high temperature methanation catalyst for the product gases of the British Gas/Lurgi Slagging Gasifier.

Studies of coal characterisation and rheology, and the viscosities of molten slags, provided important data for the operation of the gasifier. The basic chemistry of the Gas Recycle Hydrogenator (GRH) and the Fluidised Bed Hydrogenator (FBH) was also a topic of study, and carbon formation, a particular problem with FBH operation, was investigated in some detail.

With the decline of SNG research in the late 1980s, the catalyst expertise of the Division broke new ground in the development of processes for the conversion of natural gas into potentially added-value chemicals (211). Oxidative coupling of methane to ethylene was one process for which effective catalysts, in terms of conversion and selectivity, were developed. The homogeneous conversion of methane to methanol at high pressure was another process that was successfully worked upon. This was of particular interest since the gas phase conversion of methane to methanol at pressure was one of the first projects of the Basic Research Group when it was formed (212). Thus immediate use was made of old experimental results to develop a new multi-reaction computer model of the process.

Storage

In the 1970s the Division was heavily involved with the cryogenic aspects of LNG storage particularly with the prediction of vapour-liquid equilibria established in the liquefaction cycle. The measurement and prediction of densities of LNGs were important aspects in custody transfer, and the Division represented British Gas in a consortium which supported work at the US National Bureau of Standards on these topics. Theoretical studies of 'roll-over' in LNG tanks were also carried out.

A particularly fundamental contribution to the purging operations involved in the storage of natural gas was provided by the expertise developed in establishing the characteristics of flammability limits in natural gas/air mixtures (213).

Transmission

Work on transmission included the development of new techniques for the accurate measurement of large gas flows at meter installations. Although early work was successful in developing time-of-flight (148) and laser-Doppler velocity techniques, the instrument that was commercially developed with some success was the multi-path ultrasonic flowmeter, which was licensed to Daniel Instruments (214,215). In addition to its use in British Gas the meter was sold extensively overseas. By 1992 Gas Unie had installed 30 of these meters in their transmission system.

A quite separate transmission system project was the development of poison-resistant pellistor gas detectors for gas leak alarm systems in compressor cabs. These detectors were eventually licensed to Sieger Ltd.

Adsorbed Natural Gas for Vehicles

In the late 1980s, as R&T extended its range of interests to natural gas vehicles, the Physics Division became involved in the development of active carbons for the storage of natural gas in vehicles. The advantage of such systems is that they can operate at 35-40 bar, in contrast to the pressure of about 200 bars common in natural gas vehicles. Furthermore, storage tanks can be moulded to fit the vehicle with the minimum loss of baggage space. In collaboration with Sutcliffe Speakman Carbons Ltd a suitable range of carbons was developed and tested successfully in a Vauxhall Cavalier (216). Considerable impetus was given to the programme when both British Gas and Sutcliffe became members of the US-based Atlanta Gas Light Adsorbent Research Group, a consortium set up to promote and finance the development of adsorbed natural gas storage for vehicles.

Combustion Research

The fundamental study of combustion processes was a part of the Physics Division programme since the days of the Basic Research Group. High pressure combustion has already been mentioned as an early project. Other basic projects included experimental and theoretical studies of the structure and stability of diffusion flames (217); catalytic combustion of natural gas (218); the stability of pre-mixed flames (219); thermal ignition temperatures for natural gas/air mixtures (220) in relation to gas turbine tail cones, as possible sources of ignition in compressor cabs; molecular beam sampling of stable and active species from the reaction zone of a low pressure flame (221); and the computational modelling of multi-reaction combusting systems (222).

Optical methods of studying combustion systems were of particular interest. The first ever published measurement of velocities in flames by the laser-Doppler technique were made in the Physics Division (223). Laser interferometry was used for the study of explosions and flame structure. Laser-Raman spectroscopy and laser fluorescence were also applied to flames, and later a development of these, laser Raman microscopy, was applied to the measurement of coal char temperatures in the slagging gasifier. Aspects of the research of the Division were presented at the International Symposia on Combustion on a fairly continuous basis from 1974 until the Station closed.

In summary, the role of the Physics Division was a logical development, although within a quite different context, of the Basic Research Group that was formed in the mid-1960s. Although most of the staff of that period later moved to other parts of the R&T Division, or the Industry at large, the foundations were laid in the early days for a tradition which continued until the Station closed in 1993.

2.13 And so to Loughborough

This account of the work of the last thirty years of the Station has been made by tracing the development of the four Technical Divisions during this period. But in practice many areas of work were undertaken jointly by two or more Divisions, each contributing according to its disciplines and skills. This continued to an increasing extent throughout the period culminating in the adoption of matrix management by R&T, referred to in Part 1, which in effect rendered redundant the autonomous divisional structure of the kind practised at LRS and elsewhere.

Within this system of matrix management R&T became a single unit, with a management structure of resource managers on one axis and business area managers on the other - these being overseen by Technical Controllers and Programme Controllers. It soon became clear that the project leader in the centre of the axis was the person who had to make the matrix work. He or she was to control a project which could draw on resources from any division based at any of the research stations. In addition the project leader was responsible to the business area manager for the budget and for delivery of the project on time, and to the resource manager for effective management of the resource team. In these circumstances managers had staff spread over several research stations, and project leaders could draw on resources from any of them.

So the work of LRS was absorbed into the R&T programme which eventually formed the basis of research in the first years of the Gas Research Centre at Loughborough.

This account has dealt mostly with only the broad themes of research work carried out at LRS, and the references that follow represent but a fraction of the many thousands of papers and reports that were submitted to professional institutions and publications, and to internal bodies of the Industry. Little mention can be made of the countless minor investigations that were carried out in response to specific problems encountered by the Industry, nor to the many methods, techniques and devices that were invented and developed to solve these problems and to implement the broader programmes of research.

Much has been said in Part 1 of this account about the staff of LRS, often of a light-hearted and even frivolous nature. But recognition should be made of the fact that among the staff there were those who made both national and international reputations in a wide range of scientific fields. Their research was of a high quality carried out in accordance with the criterion of relevance to definite technological objectives within the Gas Industry. The legacy of their expertise, coupled with that from the other research stations, that has been handed down to the Gas Research Centre has provided the foundation on which future research in British Gas can be built.

If the gas industry can be served as well at Loughborough as it was at Fulham then there are many proud moments in store for the staff of the new centre of research.

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