History of the **Engineering Research Station** *1964 - 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 Engineering Research Station

1964 - 1993

HISTORY OF THE ENGINEERING RESEARCH STATION
1964-1993

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Part 2: People who influenced the progress of the station

Part 3: The major technological success and the consequence and/or benefits for the industry

Foreword

In the early 1960s the Deputy Chairman of the Gas Council, Sir Kenneth Hutchinson, put forward a plan to initiate gas industry research with an emphasis on mechanical engineering, metallurgy and physics, in addition to that already underway in the area of chemical sciences. In December 1963 the Gas Council Research Committee formally agreed to set up an engineering research section, initially located on the London Research Station site at Fulham.

The team grew rapidly and soon required far more extensive facilities than could be provided at Fulham. The long-debated thoughts of creating a new northern research station eventually bore fruit in the selection of a site in the new town of Killingworth, five miles north of Newcastle upon Tyne. The Engineering Research Station opened officially in January 1966.

This history of ERS attempts to capture the essence of the organisation which developed from those early conceptual decisions and the people who helped to make it what it became during the following quarter of a century. It has been arranged in three parts:

Part 1 traces the origins, establishment and growth of ERS during 29 years following the decisions in 1963.

Part 2 focuses on the people who influenced the progress of the Station and directed its activities

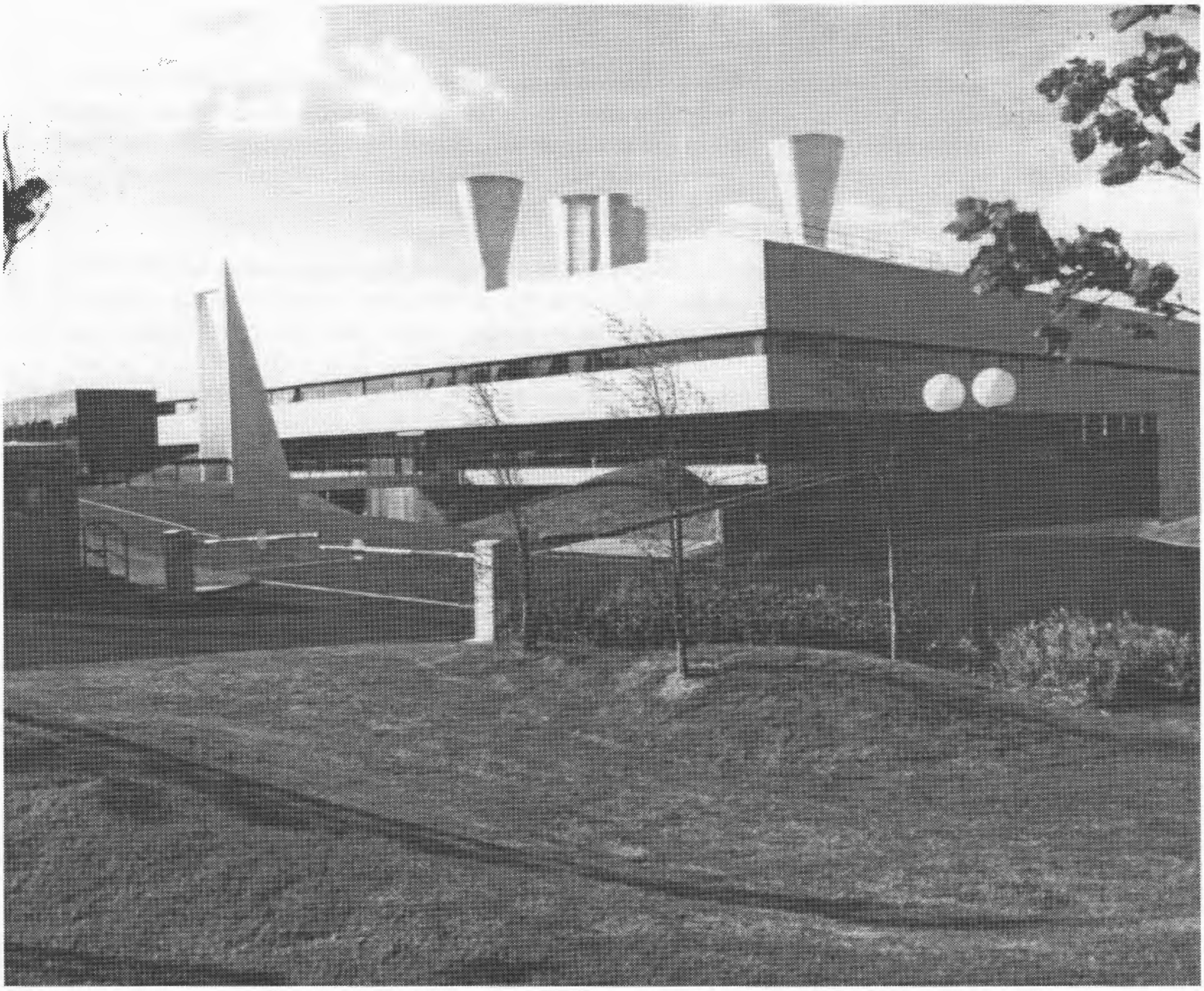
Part 3 chronicles the major technological successes and the consequences and benefits for the industry.

I would like to thank the many members of ERS staff - past and present - who have contributed to the compilation of the History. Special thanks are due to Dr Les Mercer who contributed most of Part 1, to Dr Bob Weiner for editing the text and to John Gay who has so meticulously collected photographs of events since 1966.

Because of the manner in which it has been assembled, the History is not a coherent unified text but a patchwork of contributions, views and reminiscences. I have not attempted to eliminate the variability but have decided instead to let each contribution speak for itself, and so enrich the overall picture of the people and events that have made up the life and times of ERS.

I hope the History will remind readers of the many successes achieved at ERS in their time and the part they played in them.

TOM HARRISON
September 1994



The Engineering Research Station.

Part 1 –

The Origins, Establishment, Growth and Major Milestones

1. Introduction

If an institution is seen purely in terms of bricks and mortar, ERS came to life when the Killingworth building opened on 2 January 1968. However, this is a cold and rather clinical view - it is the people that count, and this story is about the people who created and developed ERS, and their achievements, during the past twenty five plus years.

The mainstay of the gas industry from its beginnings in the early part of the 19th century until well after nationalisation in 1948, was the engineering and management of the production of coal gas. Much of the early research and development effort during that period was concerned with aspects of gas production and purification. Accordingly, it was strongly oriented towards chemistry and chemical engineering. In the early 1950s, senior members of the then Gas Council began to question the balance of applications and skills in research and it was the Gas Council's Deputy Chairman, Sir Kenneth Hutchinson, in particular, who pursued the matter and went on to propose the construction of an entirely new research station at some suitable location in the north of England. The idea did not lead to action at that time and it was not until a further ten years had passed that it began to bear fruit.

It was not until the early 1960s that the sudden acceleration of activity, resulting from the development of high pressure reforming, the plan for the importation of liquefied natural gas from Algeria and thoughts of extensive underground gas storage, brought into sharp focus the need for a new element in the research armoury. It was then Sir Kenneth Hutchinson again who put forward a positive plan to initiate research with an emphasis on mechanical engineering, metallurgy and physics, in addition to that already underway in the area of chemical sciences. The renewed debate led this time to tangible achievement. In December 1963, the Gas Council Research Committee formally agreed to set up an engineering research section within the Council's existing research organisation. The initial aims were modest. It was to 'provide a consulting service to Area Boards and keep under review the activities of other establishments engaged in engineering research'. This was an era when electricity, coal, oil, nuclear, etc. research activities had experienced rapid expansion. the new section was initially to be located on the London Research Station site at Fulham. It received a provision of £10,000 in the 1964/65 budget, a far cry from the budgets of the early 1990s, which were well in excess of £20M.

2. The London Team

With the encouragement and active involvement of Sir Charles Ellis, a leading and outspoken member of the Gas Council Research Committee, steps were taken to recruit an experienced engineer to establish and lead this new initiative.

So it was that John van der Post (Fig.1) joined the Gas Council as (The) Research Engineer in July 1964. He assumed responsibility for a number of 'ad hoc' distribution engineering-based activities underway at Fulham and soon came to grips with the urgent engineering problems facing a rapidly changing industry. The intention at the time was to establish the Research Engineer's Department within a new building being constructed

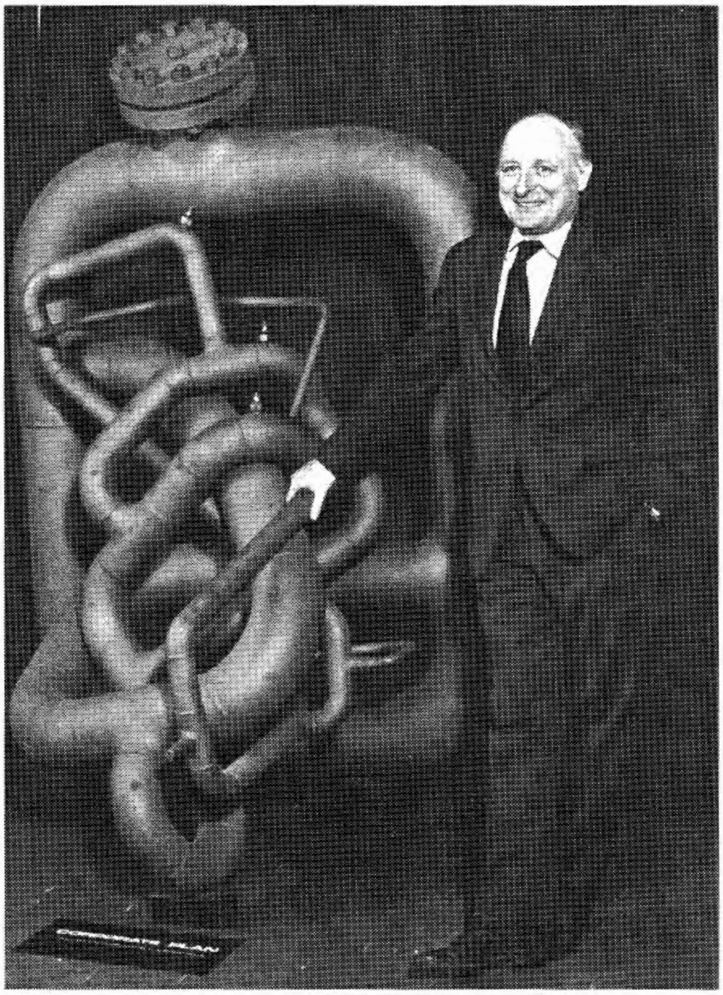


Fig. 1 John van der Post with the welded structure affectionately known as "The Corporate Plan".

on the LRS site. In characteristic manner, John immediately set to work laying down the philosophy by which engineering research would play its role covering short, medium and long term aspects and how it would integrate with other research activities, operational functions and external organisations. His approach had a strong basis of Applied Physics and the early targets were concerned with the hardware of the new oil-based methods of gas production, as well as with distribution engineering. He believed passionately that a research laboratory had to establish close working links with engineers in the field. It had to provide well-developed advisory and technical services to tackle everyday problems facing the operational engineers. Realistically, he saw that such services are the result of having an active and capable research team and not the foundation in themselves. In the early days, short-term problems came in abundance and, as ever, tended to take precedence over longer term thoughts, thus, to some extent, frustrating this philosophy. Fortunately, John was able to recruit a team of engineers and scientists with extensive experience gained in sister industries, such as defence, aircraft and nuclear power, who were able to respond rapidly to the growing problems of the new technological era then gaining ascendancy in the world of gas. Thus the scene was set for a new force in gas engineering, based in a practical manner on Applied Physics and Mechanical Engineering Design.

The initial intention was to cover four subject areas, Materials, Thermodynamics, Distribution and Control, but as recruitment of the relevant staff got underway, the plans broadened to encompass five areas. By Spring of 1965, five group leaders had been appointed covering:

- Materials (Les Mercer)
- Measurement & Control (John Fryer)
- Thermodynamics (Mike Heath)
- Engineering Science (Derek James)
- Design (Keith Richards)

With the exception of John Fryer, all were to move to Killingworth in 1966. Others incorporated into the team were Claude Littlejohn, Mike Jackman and Wilhelm Stieglitz, all of whom were previously members of LRS. The new team immediately got involved with a whole range of problems of the day, in both the gas production and distribution areas.

The first twelve months at Fulham was a period involving a great deal of site and laboratory-based trouble-shooting. For those of the team who were newcomers to the Gas Industry (the majority), it was also a period of intensive learning. In this respect John van der Post and Les Mercer were presented with a unique opportunity to meet the key 'players' within the Industry when they were invited to attend a Conference, held in Brighton on 4 May 1965, on the subject of steam-naphtha continuous reforming. (Incidentally this proved something of a baptism of fire for Les Mercer who, at that stage, had been in the Industry for only two days). The close working contacts so established proved to be of enormous value to the new team, both before and after the establishment of the research station at Killingworth. Few researchers are presented with such an opportunity, the value of which just cannot be overstated.

Much of the new team's time was taken up with the problems being experienced at that time with steam-naphtha reforming plant. The experience so gained was invaluable as it got the concept of engineering research established and ERS key people known around the Industry. From the outset then the positive drive for a 'feet on the ground' involvement with field operations was reinforced and mutually appreciated confidence and trust was established.

Not only was this a period of valued apprenticeship for the newly recruited team of 'outsiders', they also had to find ways of establishing their credibility in an Industry steeped in tradition, often with Grandfathers, Fathers and Sons following one another, generation after generation, in basically the same role. But the role was changing rapidly. New methods, new ideas and new systems came fast and furious and the 'traditional' gas engineer soon recognised, through the responsive services and extensive expertise of the new team, the value of an accessible and dependable engineering research presence.

Another strand of the early programme, which again involved much contact with Area Boards, was the investigation of the problems of leaking cast iron distribution pipes and broken hook bolts securing the bell and spigot joints. As simple as they might appear, these problems were to exercise the minds of the new engineers for many years and still feature, albeit in altered guise, to the present day. These were also the early days of experiments with plastic distribution pipes. Unfortunately the PVC materials available at the time were chemically attacked by various constituents of coal gas and cast iron remained paramount until the advent of polyethylene some years later.

The team grew steadily during that year on the Fulham site. Within weeks it outgrew its accommodation in the old 1924 building immediately adjacent to the magnificent Victorian gas holders and a new spacious office and associated laboratory area were created in the old Gas Light and Coke Company stables on Imperial Road, close to the River Thames, some three quarters of a mile from the original office.

Notwithstanding the urgent demands of the Industry's burgeoning field problems, the foundations of longer term research were laid in each of the main groups that made up the Research Engineer's team. Key topics included quantitative structural analysis, computer-based system control and studies of the fundamental relationship between properties and microstructure of materials.

An unusual 'first' was the recruitment of Denise Durand, a young French female graduate engineer. She was to make her mark, not only by being able to express herself in a forthright manner on a wide range of technical, social and political topics, but also by her significant contribution to the work on structural aspects of reforming plant. She moved with the embryo team to Newcastle in 1966 and made an equally prominent mark in Geordie society, eventually returning to France to follow a technical career, to marry and to raise a family. The Materials Group tried to go one better with the recruitment of Istvan Toth, a refugee from, and a participant in, the Hungarian uprising of 1956. A very capable individual, Istvan had mastered English within one year of arriving in the UK and went on to obtain his degree and PhD with distinction. His knowledge of high temperature refractory metals was such that, soon after the move to Newcastle, he was headhunted to join a major aerospace research team in California. Another early recruit was Dennis Clarke, who came from the Atomic Energy Authority to establish a wide range of basic metallurgical services and played a vital, and perhaps largely unsung, role until he emigrated with his family to a new life in Australia.

3. The Search for a New Site

It soon became apparent that the new engineering research activity would require far more extensive facilities than could be provided on the LRS site in Fulham. Thus the long debated thoughts of creating a new northern research station came back into the limelight. This was not before more parochial ideas were advanced to develop facilities on an old gas works site within easy reach of the London/Birmingham axis, around which most of the future growth of the Industry was envisaged. Brief consideration was given to gas works sites at Kew, Staines and Basingstoke, but the pressure to move further afield reached a new level when plans to expand the Midlands Research Station at Solihull were frustrated by Government restrictions on development in that area.

Discussions at high Government levels resulted in an eventual deal which allowed the developments at Solihull to proceed on the understanding that an entirely new Research Station would be built in one of the defined peripheral development zones. Thus, early in 1966 John van der Post was appointed Director of the proposed new Research Station and the search started in earnest. Scotland, Wales, Merseyside, the North East, the South West, parts of Yorkshire, were all on offer. The desire to maintain close working contact and good communications with the Industry, the attitude of the local authorities, the enthusiasm of the local Area Gas Board and the level of mainly indirect financial incentives, all played a role in the choice. Serious consideration was initially given to a site at the new town of Winsford in Cheshire, which was admissible within Government rules, as a (satellite) section of the Merseyside development area. Whilst preferable in terms of proximity to the major centres of gas supply and demand, it presented several uncertainties, not the least of which was the relative disinterest of the North Western Area Board.

In contrast, the enthusiasm, drive and positive assistance from Dr James Burns, Chairman of the Northern Area Board, and his senior staff, were irresistible and made the choice of Tyneside an easy decision. The Northern Area Board had moved its own HQ office only a short time before to the most prestigious site in the new town of Killingworth, some five miles north of the centre of the City of Newcastle upon Tyne. James Burns, and more particularly his Deputy, Freddie Green, recommended a site on the western boundary of the new town for the new Research Station (Fig.2). They gave much assistance, for example, by pulling together local officials and initiating discussions with a local architects' partnership, Ryder and Yates, which had designed the award winning Norgas House (the Northern Area Board HQ building).

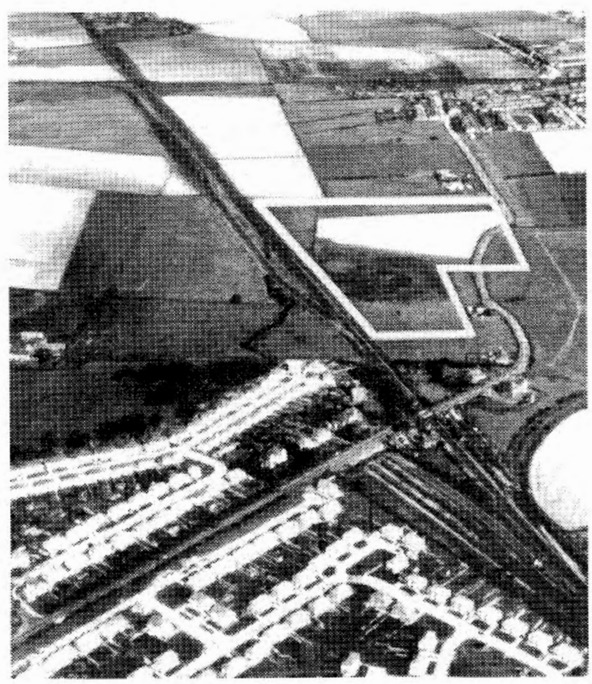


Fig. 2a The Killingworth Site – prior to development.

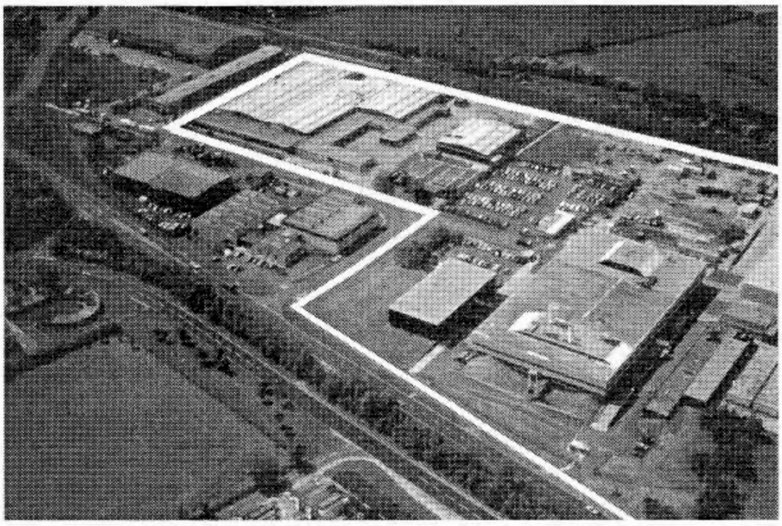


Fig. 2b Aerial view of ERS – circa 1980.

The 10 acre site was acquired for £10,000, but not without some anxious moments. During negotiations, the country went into one of the many post-war economic mini-crises and only two days before a Government crackdown on capital expenditure, the many bureaucratic requirements were met and approval to proceed obtained. Without Dr Burn's continuous, careful and direct attention, the building of ERS would at best have been long delayed and at worst might have been cancelled altogether.

Another feature of the support from Dr Burns was the provision of office accommodation for the London-based pioneers and the staff recruited in Newcastle during the Station design and construction period. A small but substantial building (Fig.3) was made available on a gas holder site on Benton Park Road in South Gosforth, midway between Killingworth and Newcastle centre. Other Board facilities, such as access to the senior staff restaurant were also generously made available. Indeed, Dr Burns was, in fictional parlance, fully the equivalent of the fairy godmother! Moreover, when Dr Burns left the Northern Area Board to become Chairman of the Southern Area Board, his successor, Leslie Clark, took on the same mantle and continued to take a great and supportive interest in the development of ERS.

4. Moving to the North East - Benton Park Road

The original team which (in alphabetical order) included Dennis Clarke, Denise Durand, Tom Harrison, Mike Heath, David Howard, Brian Huggett, Derek James, Les Mercer, John van der Post, Keith Richards and Istvan Toth, moved to the North East on 2 May 1966. Prior to this date, members of the team, and their families, had been shown around the area and initial thoughts on home location were forming. John van der Post did the really grand thing and purchased a 12 acre property some 10 miles to the west of Newcastle, complete with a fine mature stone built house, but which later proved to be more of a burden than he anticipated. Several members of the team were accommodated, on a temporary basis, in council houses which were being built close to the new site within the Killingworth Township. Several temporary bachelors came together in a couple of these properties for a time; a fact which caused some concern and much 'behind the curtains' discussion amongst the local residents.

Fig. 3 "Benton Park Road" – The first home of ERS in the North East 1966.

Once the team was safety ensconced in the North East, recruitment began in earnest. Aided and abetted by Northern Board Deputy Chairman, Freddie Green, the first appointment made by John van der Post was that of Brian Thompson, to look after administrative services, systems and procedures for the new research presence. This proved to be one of the wisest decisions taken - the well laid foundations and mature professional nature of the function quickly got things 'up and running'. They have served the Station well over many years and are still strongly apparent in the approach followed to this day. Dick Lowry, who joined the new team from Northern Gas, must also be mentioned at this stage. As Brian Thompson's 'Man Friday' he became a stalwart member of the team, a totally dependable, unflappable 'rock of ages' in all matters financial.

This period of intense recruitment also saw the appointment of three senior engineers from the aircraft industry, David Needham, Alan Spearman and Gerald Clerehugh. David and Gerald had indeed been colleagues at the Brough plant of the Hawker-Siddley Company and, in retrospect, both claim that they did not know of each other's interest in joining British Gas! All three were to play a leading role in the development of ERS and Gerald has, of course, gone on to be influential in a much wider arena.

It was also during the Benton Park Road period that the Industry decided to feature research activities in one of its national advertising campaigns. A 'specialist' PR team, complete with, then, fashionably long hair, ear-rings and green corduroy trousers, arrived one day with the rather imaginative idea of photographing one of our new bright young graduates, resplendent in ceremonial graduation garb, on the beach at the nearby seaside town of Whitley Bay. The photograph was to show him gazing out to view the sun rising from the North Sea - looking to a new dawning - the assurance both of his future and that of the Industry he was to serve. Unfortunately, for three days the North East did its worst it produced one of the most persistent frets, or sea fogs, for some time. An alternative had to be found. The team could not return to London empty handed! The outcome was 'Six of the Best', a rather undignified fish-eye lens view of six senior members of the new team who happened to be on site at Benton Park Road on the day. It was actually featured in weekend magazine advertisements! (Fig.4).

Fig. 4 "Six of the Best" as it appeared in national advertisements in 1996.

5. The New Building

The architects of the new building quickly got into their stride. They produced an imaginative, visually attractive, and yet thoroughly functional and flexible design, that has served the Industry well for almost 30 years. It is as good looking, practical and functional today as it was on the day it first opened.

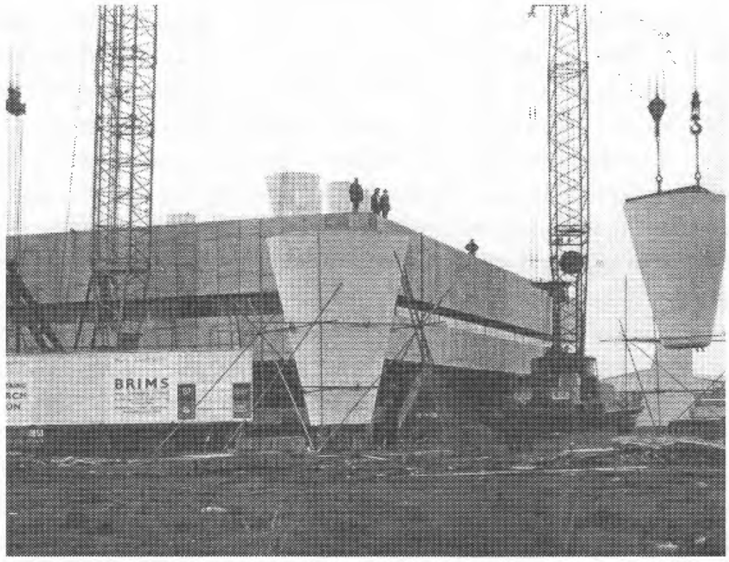


Fig. 5 Construction of the main ERS building in 1967.

Fig. 6b Transmission Electron Micrioscope with Peter Rodgerson.

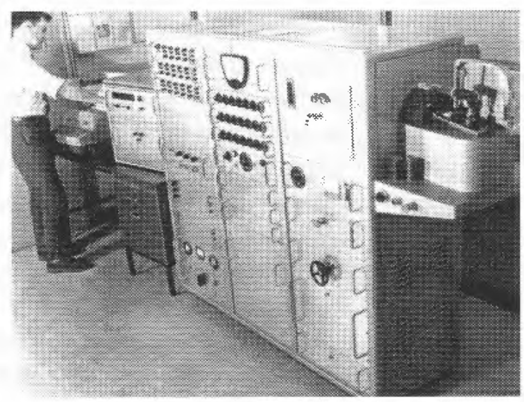
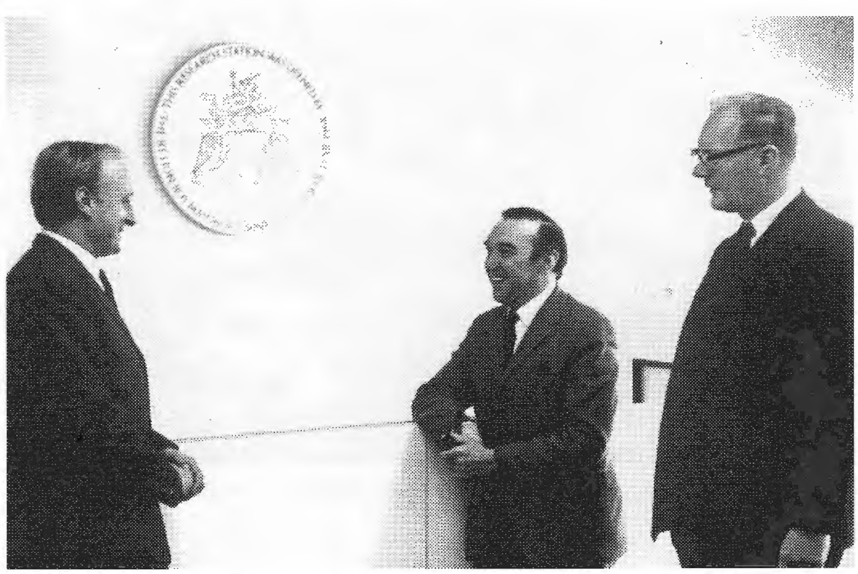


Fig. 6a The Quantavac – use for spectrographic analysis of steel – operated by Bill Lunn.

Fig. 7 NOT the opening of the Engineering Research Station.

Roy Mason – Minister of Power could not make the opening ceremony – Friday 13th December 1968 – but seen here at a later date with John van der Post (Director) and Leslie Clark (Chairman – Northern Gas Board).



No major building of this type and scale goes up without anxious moments. One of these arose from a change in the location of the plant room, which, to reduce costs, was moved from a ground level site to a position over the main reception area at the front of the building. To accommodate the much higher loads, large steel beams of unusual design were added to the structure. Just after they had been installed, a major road bridge collapsed in Australia, giving rise to wide-ranging international concern about the materials and construction methods used. A largely jocular remark about the ERS structure prompted an investigation which, at the outset, revealed many rather worrying common features. Thankfully, more careful enquiries produced a more comforting picture and the scare was quickly laid to rest. Visions of a major collapse in the new prestigious laboratory, which was the home of structural engineering for the Gas Industry, could not be imagined!

Construction began in August 1966 (Fig.5) and the building was occupied only 17 months later, on 2 January 1968. The main building, with a floor area of 74,000 sq.ft., cost £740,000. Activities were rapidly transferred and operations were in full swing within a few weeks. By May 1968, two years after the transfer of the original eleven to the North East, the staff totalled 130. Impressive new items of equipment had been installed, including a pioneering IBM 1130 computer, a Quantovac automated chemical analysis unit and an electron microscope (Fig.6a and b).

The opening ceremony, on Friday, 13 December 1968, was to have been performed by Roy Mason, the then Minister of Power, and, although the wall plaque still conveys this view to the world, the ceremony was actually performed by Reg Freeson, Parliamentary Secretary to the Minister of Power, who conveyed the absent Minister's apologies (Fig.7). This was the first significant visit to ERS of senior staff from the Gas Industry, an experience to which staff became increasingly used in the years ahead, but was then something of a unique occasion. The visitors included senior members from the Gas Council; Area Boards, and, of course, the Northern Board in particular; engineering institutions; universities; trade unions; and local dignitaries. Perhaps the best known local dignitary was none other than Dan Smith, at that time Leader of Newcastle City Council, but later to be implicated in the Poulson Scandal.

When the Killingworth building first opened it contained a veritable 'rabbit warren' of small offices and laboratories.

Fig. 8 A view of the Open Plan Office 1978.

This was anathema to John van der Post and he quickly took advantage of the remarkable flexibility that had been designed into the building. Over the space of a single weekend, the internal partitions were removed and the 'Open Plan' offices were created (Fig.8). This was mourned by those losing privacy but rapidly found favour with the majority. Newcomers to the Laboratory found the concept very much to their liking, especially when compared with facilities elsewhere. Few changes have been made to the layout over the years and it remains as yet another example of an early decision standing the test of time.

As the staffing numbers increased, so the need for office space became ever more pressing and little by little the laboratories from the top floor were moved to the ground floor. The last remaining laboratory on the top floor was the Chemistry/Corrosion lab. managed by Tom Harrison, and only remained there because of the problems associated with removing it. However, as far as the Director was concerned, the final straw came with the inadvertent release of hydrogen sulphide from the 'gas lab' which was blown back into the building via the intake ducts on the roof, resulting in the evacuation of the lab and a temporary end to the working day. The Director's office, unfortunately, was first in line for the contaminated air and the resultant comments/expletives forced the chemists to make a now willing departure to the ground floor, where they have remained ever since.

6. Initial Management and Organisation Concepts

As will be described in more detail in Part 2, from the outset John van der Post demonstrated impressive leadership qualities, and not just in respect of technology. He introduced a whole series of advanced ideas on organisation and management of his team. He had vision and laid plans which, at the outset, may not have been entirely clear in their intent to his management team, but which moulded the Station and contributed greatly to its long term success and growth.

Reference has already been made to John's drive for a core of well educated and imaginative staff to grapple with the many and growing problems of the Industry in a practical, but at the same time, knowledgeable and analytical manner. He laid the foundations for 'down to earth' everyday testing and evaluation of materials, components and systems, alongside the basic and more fundamental studies. His early plans laid great emphasis on the full meaning and implementation of well founded engineering design. He gave deep attention to the commercial realisation of R&D activities, with great stress on the development of engineering standards, codes of practice and quality assurance methods. Work included network analysis, laboratory and field trials of engineering equipment, in-depth studies into gas flow behaviour and control and into large scale gas related hazards. He recognised that the pursuit of quality and the proper application of what was already known, would produce far greater returns to the rapidly changing Industry than any amount of new research.

In summary then, his basic thesis was that the Engineering Research Station should not be so much a research unit as an advanced engineering centre based on design and development. He also believed that the role of this centre could be divided in three ways:

a. by the type of work which it was doing,
b. by the communications for which it was responsible,
c. by the timescale in which it expected to produce results.

By April 1967, John's ideas had been translated into reality by the establishment of a structure based on three technical divisions; Research, Engineering and Technical Services, together with Administration Division.

7. Initial Technological Developments

It became apparent quite early on, that major sections of British industry had sunk low in the approach to quality and reliability. Many difficulties encountered in the building, commissioning and operation of gas industry plant came back to this serious and sad state of affairs. John van der Post did not hesitate. Whilst hardly a key remit of an R&D function, he set out to recruit an experienced engineer to establish an operational Quality Assurance team, not so much to do research, but to provide a comprehensive service on behalf of the engineering side of the gas business.' The outcome was the appointment of

Ron Gibbon to the first QA post at ERS, in July 1966. His efforts and the tangible early successes led to the transfer of the activity, in 1968, to the Production and Supply Division of the Gas Council, located at the Council's London Headquarters and headed by the, then, Mr Denis Rooke. The Inspector Approvals Scheme was an important part of this initiative. It continued to operate at ERS until it was transferred to an operational department in 1989. In total some 11,500 inspectors were examined over the years and the term 'ERS Approved Inspector' became synonymous with quality and reliability in respect of pipeline construction and maintenance operations around the globe.

Work on the Industry's many engineering problems associated with the steam-naphtha reforming process continued, following the move to the North East. Indeed, the very first paper from ERS to the Institution of Gas Engineers (IGE) was on this topic. The paper, entitled 'Metallurgical Aspects of High Temperature Reformer Furnace Alloys' was presented by Les Mercer and Bob Baker (of the British Welding Research Association - later to become The Welding Institute) to the Autumn Research Meeting of the IGE in November 1966. This outlined some of the factors behind plant failures and set out the basis of research and the resultant understanding of new high temperature materials. A major study of the critical outlet header of the basic tubular reformer led to an important milestone, when the huge variety of individual designs brought into service were rationalised down to just five altogether, with a recommendation that a more shock tolerant material be utilised for all new and replacement units throughout the country. The study required a combination of fundamental research into the structural behaviour of materials and a deep understanding of plant design and control. Extensive discussions and negotiations were conducted with designers, manufacturers, component suppliers and plant operators, both at home and overseas. A paper by Les Mercer of the major findings and practical design recommendations, was presented to an international Symposium held in Brussels in September 1968. This was the first of many papers emanating from ERS to be presented overseas.

8. 1967 - The Switch to Gas Transportation

Following the discoveries of abundant quantities of methane under the North Sea, it had become clear, even before the move to the North East, that the new engineering research team would need to invest an increasing proportion of its resources in natural gas transportation matters, covering both high (transmission) and low (distribution) pressures.

Notwithstanding continuing calls for assistance from gas production plant personnel, John van der Post took a brave decision, early in 1967, to positively realign the attentions of his team away from production plant technology and towards transmission and distribution problems. By May 1967, one year after moving out of London, when the team totalled 60 persons, 95% of the available effort had been switched to these areas. This is the way it remained, other work either being stopped in its tracks or being transferred elsewhere within R&D or to Area Board laboratories. For example, virtually all the materials and corrosion work associated with gas production went back south to LRS.

While the redeployment of resources to gas transportation benefited both transmission and distribution work, the initial balance was heavily in favour of transmission, as that was where the most pressing problems were perceived to be. Over the following years the balance shifted with expenditure on distribution projects gradually assuming more and more prominence, especially so after a major explosion in 1971 at Clarkston Toll in Scotland. The late 1960s must, however, be characterised as years of intense effort on transmission related problems and it is with this work that the ERS story will continue.

9. ERS and the National Transmission System

The wholesale move to naphtha reforming, utilising plant with an output at least an order of magnitude greater than the old coal fired retorts, brought in the construction of Area Board 'Supergrids'. These high pressure steel pipelines, which were largely based on American standards, preceded the construction of the UK national system, although the 18 inch 'backbone' pipeline had been laid in the early 60s to carry gas from the Canvey Island liquid methane terminal to Manchester and Leeds and several points of the country en route. Early work on the national system from the Easington and Bacton east coast terminals in the late 60s, revealed many deficiencies in then current methods of design, materials specification, construction and testing.

Hence, the creation of ERS was well timed! A brand new state of the art laboratory, with leading edge functional and aesthetic qualities, contributed much to the excitement and driving force of those fast changing times. The recruitment of highly qualified and skilled personnel moved forward at a healthy pace with the rapid development of the programme. Such was the pace, that authorisation was sought and granted for an extension to the new laboratory within two years of it opening. The immediate technical priorities were the problems of the day out in the field. The early organisation of ERS reflected this, but, at the same time, catered for the future by laying the foundations of longer term thinking through focused recruitment of carefully selected key skills. This was described by John van der Post in his first paper to the IGE in November 1967.

Just a few months later, in a paper presented by all four Station Directors to the 1968 IGE Spring Meeting, John van der Post outlined the developing pattern of the organisation, with a structure based on four divisions, covering Research, Engineering, Development and Laboratory Services. Responsibility for tackling problems of the day was spread across the whole organisation, but the Research function was, to some extent, shielded from them. The approach was based on Design and Materials and priority was given to the obvious (with the benefit of hindsight!) features of defining the problem and setting the required specifications.

At this stage, the majority of the existing relevant specifications were American. Indeed, American know-how in high pressure pipeline technology was enormously helpful during those early days. Both formal and informal arrangements were made for close and continuing exchanges of both field and research experience. An ERS representative served on the User Committee of the American Petroleum Institute (API) over a period of several years and played a role in getting research findings incorporated into internationally utilised specifications. Perhaps the most significant link was that forged with the American Pipeline Research Committee (PRC) which, following its founding in 1952, became the mainstay of co-operative R&D for the decentralised American transmission pipeline industry. This link was warm and close from the outset and remains active to the present day.

Despite being given an excellent start on the basis of existing American specifications and standards, many problems soon emerged, as mentioned earlier with methods of design, materials specification, construction and testing. For example, American experience had shown that high pressure natural gas pipelines could be subject to very long brittle fractures and yet no fracture resistance provision was written into existing materials specifications. Similarly, stress corrosion cracking was known to be a problem, but the mechanism was not understood and hence appropriate protective measures could not be accurately targeted. Little was known about the flow of gas under transient conditions and, in the measurement and control of gas flow, purchasers of equipment had to depend on the information provided by suppliers. These and many more problems faced ERS at the outset and to find solutions required a variety of approaches, ranging from large scale tests to pencil and paper (or later computer-based) theoretical exercises.

While the facilities at Killingworth were intended for small and medium scale testing (Fig.9a and b), it became clear at a very early stage that the site simply would not be suitable for some of the work that needed to be undertaken. The first such requirement that arose was for a facility at which fracture tests could be conducted on full-scale pneumatically pressurised transmission linepipe. The problem here was that, with the wrong type of steel (i.e. one which fractured in the brittle mode), fragments could be projected for distances of as much as quarter of a mile. Additionally, where methane was used as the pressurising medium, there was the danger of a fire-ball if ignition took place. Clearly then there was a need for a facility at a remote spot, where the experimenters could put some distance between the general public (and indeed themselves) and the tests. Suitable sites were found at Otterburn in Northumberland and Spadeadam in Cumbria.

It had also become evident that full-scale evaluations would be required on the various types of flow control and measuring equipment used in the transmission system. Access was therefore required to a transmission pipeline off-take and, with the co-operation of the (then) Pipelines Division, facilities were built at Low Thornley and Bishop Auckland, both situated in County Durham.

The development and some of the work done at these Outstations is described in the next three sections.

10. Otterburn 1966 to 1978

The Test Site

After some preliminary tests at Spadeadam, which at that time proved to be an unsuitable location, the first site for large-scale testing was located within a Ministry of Defence Training Area at Otterburn, in north west Northumberland (Fig.10a and b). This training area extends over some 250 sq.km of remote moorland to the south of the Cheviot Hills, and ERS was allocated a site, known as Bellshiel Law, which is a plateau about 300 metres above sea level.

Owing to its extensive use for military training, Otterburn is noted for its barrages of noise, so that the additional solitary explosion, due to British Gas testing, caused little concern in the surrounding areas. In consequence, it was possible to operate throughout the 12 years of experimental activity at Otterburn, without arousing public concern or interference, an important benefit, especially at early stages of the development of the Transmission system.

The Initial Installation

Fracture testing of full-scale gas pipelines was not new, the Battelle Memorial Institute (BMI) in the USA, had conducted such work during the mid-19SOs to 1960s for the American Gas Association. The (then) Gas Council was able to benefit from this body of knowledge and ERS engineers, under the able 'on site' leadership of Dennis Jude, strove hard not to 'reinvent the wheel'.

The installation allowed full-scale tests to be carried out either on single 40ft pipe lengths, or on multiple 600ft pipe lengths. Many of the tests were coupled with heat exchangers to enable heating or cooling of the pressurised pipe to be carried out.

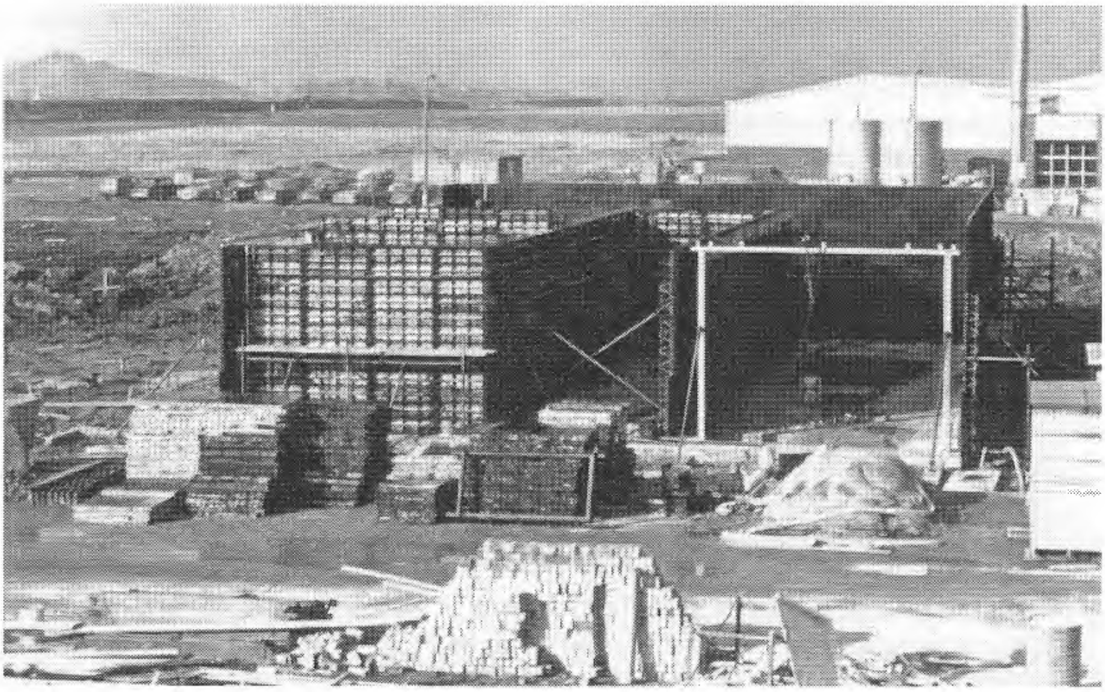


Fig. 9a Construction of the Test Cell Facility in 1969.

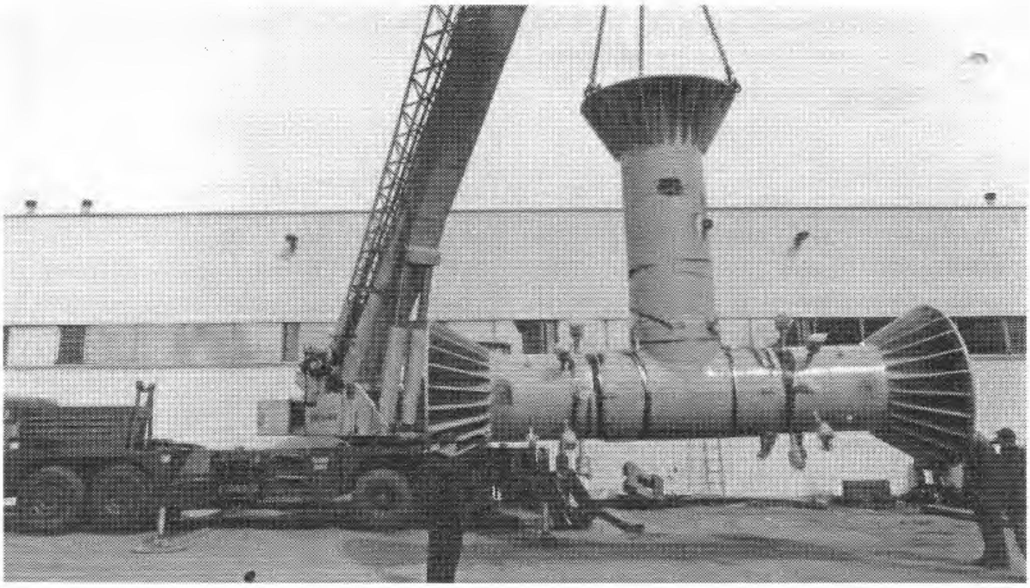


Fig. 9b "Too big for the Test Cells" – this T junction is being loaded for transport to Rosyth Naval Dockyard.

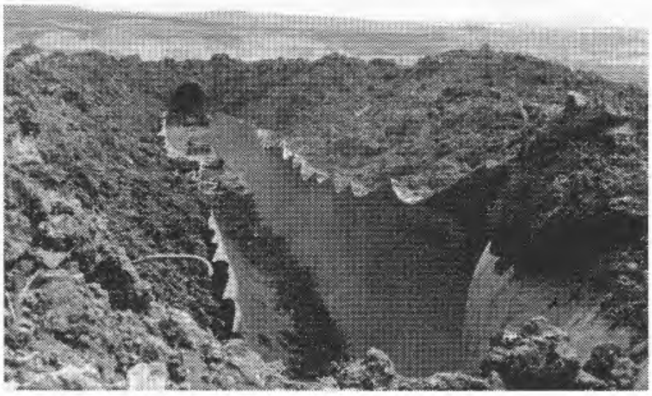


Fig. 10a Otterburn Test Site.

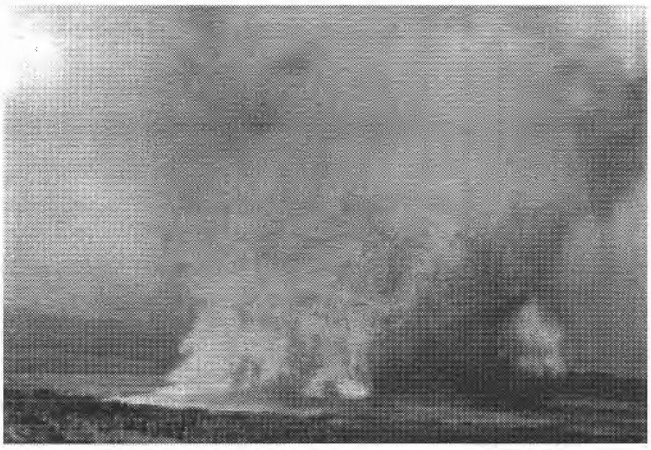


Fig. 10b Fireball Test.

From the outset, a procedure was set up which ensured that a great deal of the preparatory work on the pipes was completed at ERS before despatching to site. This included the installation of critical measurement devices. The sub-assemblies were then welded and connected to buried reservoirs. A cable system linked the measurement devices to the data logging facilities which, because of planning restrictions, were housed in a purpose-built caravan located on-site for the test period only. This 'everything must move' philosophy had undoubted benefits in future operations.

The first test series examined the behaviour of pipes which fractured in the brittle mode. These tests were conducted with either air or nitrogen. Although the decompression speed of natural gas is faster than either, it was shown that this difference did not affect the results.

By 1970 the programme of experimental verification of the theoretical analysis, which established pipe resistance to brittle fracture as a function of pipe wall stress and temperature, was completed.

In parallel with propagation testing, there was also a programme of impact tests on pressurised linepipe. These eventually demonstrated that, compared to sleeving, thick walled pipe was economically a more viable alternative, a result which became embodied in the IGE TD1 pipeline 'code'.

The scale of these operations in the early years can be judged by the site's logistics which saw the successful completion of 72 tests (43 propagation, 29 impact), during the 20 months prior to March 1970.

Site Development and Contract Operation

In the early 1970s US operating experience showed that even specifications calling for ductile fracture at pipe minimum operating temperatures were inadequate because of the possibility of long running ductile fractures. Fortunately this was revealed before further ordering for new UK lines had commenced.

It now became necessary to provide an installation in which tests pressurised with natural gas could be conducted, so as to produce an accurate simulation of ductile fracture in a complete transmission line. This experimental and analytical work was effectively completed by late 1974 and established the criteria embodied in the British Gas toughness specification for land-based pipelines.

From 1975 the Otterburn site tended to be used for test programmes under contract to external sponsors. One such contract led to further development of the site facilities. This contract was concerned with an offshore gas line, conveying a 'rich' gas at a pressure of 138 bar. A mini process plant was incorporated into the existing systems to handle the additional contributions of ethane, propane, butane and pentane, brought in by road tanker. Additionally, a mobile chromatography laboratory, supplied by a heated sampling line, controlled this build-up to the specified target composition.

The Move to Spadeadam

It gradually became apparent that the frequency of British Gas testing was causing difficulties with Army Training programmes, because of the long periods of closure of the site access roads. An examination of suitable areas in the UK, redundant to Ministry of Defence needs, identified one such area, located at Spadeadam, under the control of the RAF, and, in July 1977, British Gas were given permission to lease a part of that site.

11. The Spadeadam Test Facility

Fig. 11a Aerial view of the Spadeadam Site.

Getting Started

Spadeadam is not one site but a collection of facilities spread over a 13 square mile area of the Kielder Forest, the largest manmade forest in Europe. In 1977, Brian Flood, John Edwards and Alec Greener, opened up the Spadeadam site for full scale testing. Dennis Jude transferred his team from Otterburn to the site, trenches were dug, pipes laid and preparations were made for testing to begin (Fig.lla).

It was soon realised that a feature of the site was the almost continuous rainfall, which turned the test area into a quagmire. This could only be overcome by the laying of nylon sheet covered with the first of hundreds of lorry loads of hogging; small stones from local quarries.

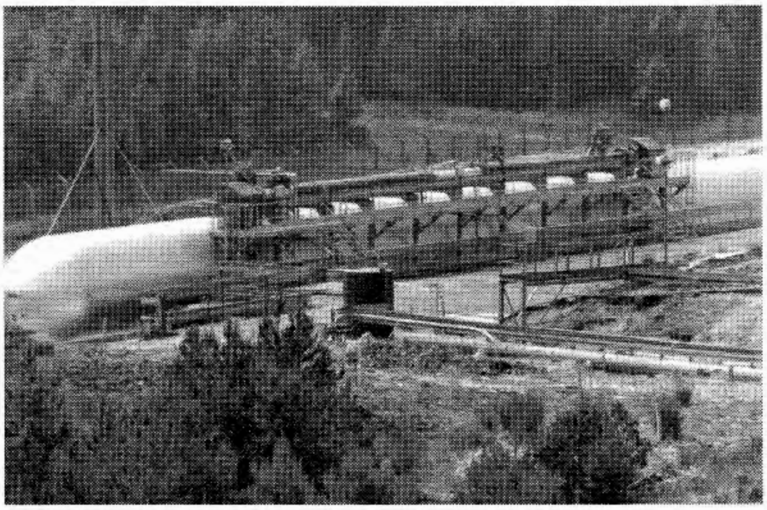


Fig. 11b High Pressure "Sour Gas" Test Rig.

The move to Spadeadam also coincided with the start of a long and productive co-operation between the Engineering Research Station and the Midlands Research Station. In fact, Midlands Research Station engineers were the first to carry out tests on the site, exploding gas-air and gas-oxygen mixtures. It was these tests that began a further long relationship between British Gas, the nearby farmers, residents of Gilsland, Haltwhistle, and under certain weather conditions, people even further away who could hear the tests.

Pipeline Programmes

The principal reason for the leasing of the site was, however, the testing of transmission pipe and other large diameter pipes produced by many European and British manufacturers, much of the work being under contract to external sponsors.

For example, in 1982 the Japanese requested full-scale fracture propagation tests on pipe which they were planning to sell into the Russian market. The problems they had in Japan were that, while they could test using air as the pressurising medium, they were not allowed, for safety reasons to use natural gas, and pipes had to be tested with natural gas at low temperatures. Dennis Jude put together some of the most complicated full scale fracture propagation equipment ever used, so as to meet the precise test conditions required by the Japanese.

This work was carried out successfully and led to the Japanese asking the site to construct facilities to carry out work involving toxic gas (H_2S) while studying the growth of hydrogen induced cracks in pipeline steels. Similar work was later carried out for a consortium of British companies (Fig.llb).

As the site grew Alan Stevenson was appointed local Manager, having been transferred from the Experimental Engineering Group at Killingworth. Under his stewardship the site played host to Sir Denis Rooke and the Research Committee, a very memorable visit, for which a special coach was hired so that the Research Committee would be able to see tests and video tapes of tests while sheltered from the (anticipated usual) pouring rain. Suffice it to say that on the day Sir Denis visited the site the sun shone and the party went from test facility to test facility in relative comfort viewing the work being carried out.

Ignition Hazards Programmes

A project commissioned by Shell initially examined the consequences of the ignition of an accidental spillage of fuel and later also covered work on unconfined vapour cloud explosion problems. Subsequently this latter work was carried on by the Midlands Research Station in a different way, resulting in larger and larger facilities being introduced onto the site year by year.

Offshore Programmes

Following the Piper Alpha disaster the facilities concentrated more and more on the effects of massed pipework on the progress of an explosion and on the level of resulting overpressure.

As these developments took place, the site swapped Stevensons. Alan Stevenson left British Gas to further his career elsewhere and was replaced by Robin Stephenson, as the Site Manager. Under Robin Stephenson's direction, the site extended ignition hazard work, on behalf of British Gas, Shell and equipment manufacturers, to testing the resistance of panels used in offshore modules to blast loads and to the impingement of flames.

Work for Midlands Research Station

The release and dispersion of gas and the radiation from jet fires, trench fires and flare stacks, have been the subjects of investigations by the Midlands Research Station at Spadeadam for many years. As part of this work, they have been developing LIDAR, a laser-based device which enables the density of natural gas in clouds of gas-air mixture to be measured at a distance.

Since 1977 the site has grown enormously. It now uses over 400 tons of liquefied natural gas every year and half as much again of liquid nitrogen, in carrying out the test programme. In a bustling test week, nearly 100 people can be expected to be on site.

12. Low Thornley and Bishop Auckland

One of the many complex technical problems thrown up by the construction of the National Transmission Grid concerned the selection and operation of flow control and measurement equipment. It quickly became apparent that a facility was required in which manufacturers' claims could be put to the test and development work on new equipment carried out in conditions as similar as possible to actual service. The best equipment could then be selected and the information obtained could be used to help Regional Engineers. In the late 1960s, existing codes of practice were of little help in predicting behaviour of systems under changing load and varying pressure conditions, understanding modes of failure, the sensitivity of components to environmental conditions, relief valve venting capacities, and what regulators, relief valves, and meters to buy. The problem was compounded by manufacturers who were notoriously optimistic about the claimed performance characteristics of equipment.

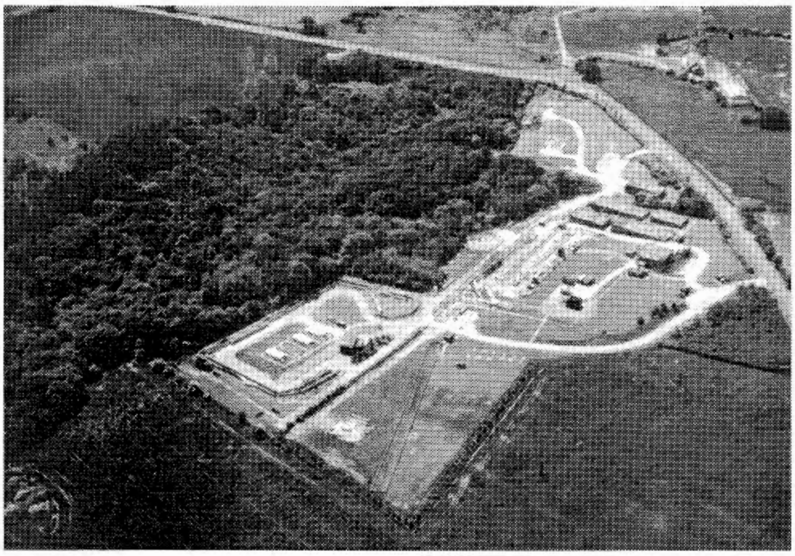


Fig. 12a Aerial view of the Low Thornley Test Facility

Low Thornley

To meet these requirements, the Low Thornley test site was built in 1969 on a five acre site, 13 miles south of the Research Station (Fig.12a). It was built at the point where gas was transferred from the new National Transmission network to the Northern Gas Region. At this point, it was possible to borrow gas at pressures of up to 70 bar, utilise it to conduct tests, and then send it on its way to the customer at a lower pressure.

Initial responsibility for the site went to Dave Needham, who engaged another practical engineer, Jim Parry, to carry out the co-ordinating, planning and building of the site. The site, with its compact network of pipes of different sizes, was designed rather like a grand Meccano set, in which much of the pipework can be rebuilt over and over again, giving enormous versatility for testing components and layouts in ways that simulate all types of field installations. Once completed, test programmes at the Outstation were managed by Brian Bennett-Cowell, who eventually also became responsible for the Bishop Auckland site until his retirement in 1993.

The nerve centre of the complex is the control building. Here, flowrates, test pressures and temperatures are remotely controlled, key operating conditions are displayed and monitored, and alarms warn of potential hazards. Accurate test data, relating to the performance of the components undergoing tests, are transmitted to the control room where they are processed by on-line computer to give performance characteristics almost immediately.

Very accurate flow measurement standards enable the site to calibrate and study the accuracy, at working pressures, of a wide range of experimental data needed to establish codes of practice for offtake flowmetering and for commercial and industrial metering installations.

During the 1970s, the site acquired pig testing loops in order to assess the new on-line inspection vehicles that were being developed at ERS. Three high pressure pipeline loops of 12in, 24in, and 36in dia. were installed to simulate the kind of environment, obstacles and wide range of pipeline defects that an intelligent pig might encounter in service. Each of the loops was equipped with fittings, bends, deformities, defective sections and simulated river crossings.

In order to aid the development of an offshore pig, the 36in dia. pig loop was later fitted with a sea water tank to simulate sub-sea conditions. The main features were a deliberately damaged section of concrete coated pipe and the ability to vary the depth of sand covering the pipe in the tank; the latter simulating a variation in the level of sedimentary backfill layers covering pipelines on the seabed.

Another facility of the Low Thornley site, was the work devoted to evaluating the performance characteristics of the new production governor module cartridge. Here, cartridges coming off the manufacturer's production line could be tested at the rate of 40 per month, using semi-automatic testing procedures.

In 1975 it was decided by British Gas that, some time in the Autumn of 1981, the pipeline from which Low Thornley borrowed its gas was to be downrated from 70 bar nominal to 38 bar. To do nothing and accept a maximum inlet pressure of 38 bar would have severely limited the range of equipment which could be tested. The provision of an on-site compressor station to raise the pressure to 70 bar was considered, but the idea was discarded as being too expensive.

There was, therefore, only one real alternative - to build a new test site. A number of possible sites were examined, offering high pressure gas at the inlet, a lower pressure discharge and an adequate flowrate.

Bishop Auckland

Fig. 12b Aerial view of the Bishop Auckland Test Facility.

A suitable site was found at Bishop Auckland (Fig.12b), where high pressure gas was available at the outlet of a compressor station. The lower pressure discharge would be the proposed downrated Northern feeder. The choice of site also presented the tempting opportunity of passing flowrates through the site, which are truly representative of those in the large diameter transmission feeders, i.e. 50 x 10 scfh, about eight times the capacity of the Low Thornley test site. Financial support was given for this highly desirable feature and therefore the site was designed to operate in two distinct modes of operation.

(1) Tests involving large pressure drops (regulators, noise evaluation trials, etc) discharging gas into the downrated Northern feeder.

(2) Steady state flowrate trials with minimum pressure drop (metering, vibration analysis) discharging gas into the transmission feeder.

Both modes use a common inlet from the discharge site of the compressor station.

Many lessons learnt in operating the Low Thornley site were applied at Bishop Auckland. In the areas of safety, slam shut valves were installed for quick isolation of the site, if necessary, from the grid. Other additional facilities included accurate instrumentation, high speed data collection using on-line computers and critical nozzle, primary metering standards ensuring traceability to national and international standards.

Alan Spearman was given responsibility for the development of the site, while the mechanical and civil engineering layouts were provided by a team of designers at Pipelines Dept. Hinckley, working under ERS conceptual guidance. On site construction was carried out by the Project Construction Department of the same group, the building designs by the Architects of the West Midlands Region, the instrumentation and data collection equipment by ERS. Teamwork on a grand scale.

The £4 million project was completed in 1981 and commissioned early in 1982. It immediately proved its worth in the calibration of 30 turbine meters destined for the Rough storage project, the development of the ERS high capacity regulator, and the development of the LRS 4-path ultrasonic meter. Because of the uniqueness of the facility, BP in Alaska asked ERS to calibrate two venturi meters of 30in dia and 24in dia. These were completed successfully.

The Bishop Auckland test site, like Low Thornley, which is still operational in medium pressure operations, has demonstrated that it is an invaluable aid to engineers in the development of new equipment and techniques in the Company. Both test sites present working conditions in which the performance characteristics of transmission components can be studied over a wide range of operating conditions, thus assisting in the selection of components, enhancing safety and leading to economies of operation.

13. An Overview of the Major Transmission Projects

In parallel with the work of the Outstations, the majority of the resources of the Station were devoted to the medium and small scale research programmes being undertaken at Killingworth. While detailed accounts of the major transmission projects are given in Section 3, brief reference will be made here to some aspects of these, in order to illustrate the range of problems tackled by ERS.

The early days for ERS in pipeline engineering presented many challenges - technical, commercial and political! A major campaign brought a reluctant UK steel industry into the realms of quality and reliability, but not before substantial quantities of large diameter pipe had been imported from more go-ahead continental European suppliers. ERS worked closely with UK manufacturers to overcome the wide ranging problems, directly influencing operations in the mills and establishing new and searching test methods (Fig.13). This is where Ron Gibbon, ably assisted by Russ Lumb, late of the Atomic Energy Authority, made their mark.

Research proceeded alongside all this urgent 'trouble shooting' activity. In order to examine the severity of the fracture resistance problem, tests on full scale pipeline fracture behaviour were undertaken, as has been described in the preceding sections. This programme brought ERS onto the scene as a world-leading player and in later days much work was done under contract for international bodies, covering pipelines destined for operation in remote and often inhospitable parts of the world, both on and offshore. The Station was a founder member of the European Pipeline Research Group (EPRG) formed under the auspices of the Coal and Steel Community in 1972 and it ran a major International Pipeline Fracture Conference in Newcastle in 1974.

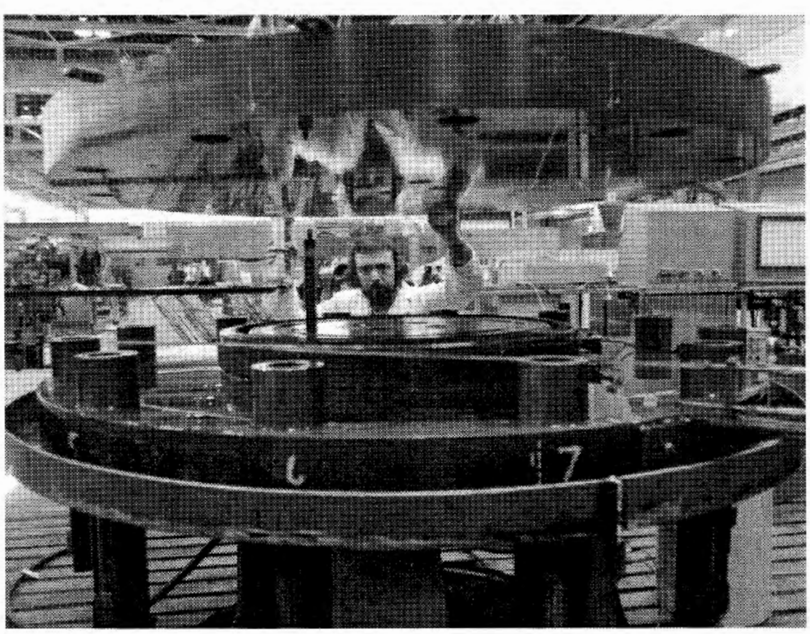


Fig. 13 Ring Tension Test Machine (operated by Jack Coatsworth). – Used for accurate strength measurement on whole pipe sections.

Investigations of high pressure (yield level) testing of pipelines led to the introduction of single wall X-radiography of field welds and of the establishment of the Inspector Approvals scheme at Killingworth.

Finding faults before they lead to failure is vital. Preventing the faults in the first place is a worthy and usually economic objective. Pipelines are buried in the ground and are subjected to the aggressive forces of corrosion. Corrosion control technology had featured strongly in the ERS portfolio of skills from the outset. Tom Harrison and his team played a vital role in the understanding of corrosion processes and the means of their control in all areas of gas transportation technology.

Scientific studies into the mechanism of pipeline stress corrosion cracking were underway even before the new Killingworth building was occupied in January 1968. A specialised coatings section was created and the Station played a significant role in drawing up the necessary performance specifications and in encouraging the establishment of British Pipe Coaters Ltd (BPCL). This company, with a 51% ownership by British Gas, has coated vast majority of onshore pipelines for British Gas and a sizeable proportion of all offshore pipelines on the UK continental shelf. Les Mercer was the longest serving Director of the company when he resigned on his retirement from British Gas at the end of 1993.

As described earlier, the initial purpose of the Low Thornley gas flow testing site, was to evaluate flow control and measurement equipment. In support of this activity there was a major drive to develop close communications with the principal suppliers of engineering equipment to the Industry. Under the direction of the Distribution Engineers' Committee (DEC), the Killingworth Testing Facilities Panel was set up. This had the demanding task of checking and approving equipment destined for use in the gas distribution system. Notwithstanding the expectations of field engineers, the sheer range of equipment on the market meant that the exercise became a 'disapproval' rather than an exclusive 'approvals' service. Hence, any equipment could be used at the individual engineer's discretion, but if it was found wanting, and this was confirmed and quantified in testing as requested by the overseeing Panel, then its use was formally discouraged throughout the Industry. The expanding links provided a two way 'trade off' outside the gas business and, in particular, with sister industries in the UK nationalised sector. It involved Trade Associations and the like, both home and overseas. Over the years the scope of the Low Thornley and Bishop Auckland facilities was widely extended, encompassing the testing of intelligent pigs, the effects of ignited gas releases on adjacent pressure vessels and the performance of an extensive range of distribution equipment.

Whilst much of the work at ERS was founded on structural engineering and materials technology, skills were also developed relevant to the handling, control and measurement of gas contained within the extensive and growing pipeline system. Mathematical simulation of gas flow in pipeline networks started as early as 1966 under the guidance of Mike Heath, a member of the founding team at Fulham. Models dealing with transient flow were described in a paper by John Blunt and Mike Heath, presented to the IGE in November 1968. A further presentation was made by David Needham to the IGU World Gas Conference held in Moscow in 1970. This work was probably the first at ERS to make extensive use of the, then, rapidly developing field of electronic computing. The flow modelling work was transferred to LRS in 1974, where a more substantial team of appropriate skills was being established. With the reorganisation of research throughout British Gas R&D in 1992/93, most of the activity returned to ERS - the process had come full circle after a period of some 20 years!

14. The 1970s - The Expansion of Distribution Activities

As has been mentioned earlier, when John van der Post arrived at Fulham in 1964 he was immediately confronted with urgent problems in the field involving joint leakage in cast iron distribution mains. Keith Richards and David Howard played a key role in all this work and were primarily responsible for maintaining the momentum and getting an expanding programme underway in the North (Fig.14). Hence, gas distribution preceded

Fig. 14 Members of ERS Senior Management familiarising themselves with basic distribution technology at the Holdsworth Training School (North West Region).

Left to Right – Mike Rouse, John van der Post, Gerry Clerehugh, Harry Tishler, John Newcombe, Roy Wilkins and Brian Phelps.

all other things in the new engineering research portfolio and it later grew to dominate the Killingworth programme. It was there at the beginning and remains to this day as a substantial, active and productive component of the research programme.

Low pressure gas distribution dates back to the early 19th Century, although cast iron only made a major impact after 1850. Gas distribution technology then changed little over the next one hundred or so years. Few saw the need for, or indeed the potential value of, 'boffin' based research as cast iron was cheap and was regarded as long lasting and reliable. The work which ERS commenced in the distribution area was, therefore, a marked departure from the norm on the world scene. It was, however, soon to show what could be achieved by the proper application of sound scientific and engineering principles to what many saw as a fully mature activity.

New problems were, in fact, just around the corner, associated with the introduction of dry reformer gas and, later, natural gas. Joints began to dry out and leakage became an increasingly serious economic problem. New methods, and in particular new materials, were perhaps necessary after all! The growing importance of work in the distribution area can best be judged by the changing budget allocations and their relation to operational expenditure between 1964 and 1984.

Year	**R&D Budget**	**% Operational Expenditure**
1964	£ 5,000	0.008
1974	£1,150,000	.7
1984	£7,200,000	1.25

The topic clearly 'came of age' during this time and a new era was born, involving work which was to become probably the most significant in the ERS portfolio. Over the years, the work produced many imitators and, as with transmission technology, ERS became a regular port of call on the international gas traveller's itinerary.

In the beginning, leakage control in the largely cast iron system was the main focus of activity. Ineffective leak-clamps were improved and new designs developed. Joint repair by encapsulation was introduced through joint ERS/LRS activities and the output licensed to manufacturers to provide commercial scale supplies to the Industry. At the end of the first 25 years, the interest is still in cast iron! But now it is the application of intelligent pig technology to finding areas of severe corrosion to help fix priorities for replacement.

A great deal took place in-between and again some examples of the projects undertaken are given, simply to illustrate the wide range of these.

ERS pioneered OR type studies of the Distribution system. The conversion to natural gas provided a unique opportunity for the accurate measurement of leakage. Much of this early base-line work is described in a Gold Medal winning paper, presented to the IGE in November 1970 by Alan Spearman, the late Maurice Tanner (LRS) and Bill Pickering (ex Emgas). In parallel, more economic means of leakage control were explored jointly with LRS. Oil fogging of rubber jointed mains was introduced in 1974, to be followed by glycol fogging of hemp jointed systems.

The serious gas explosion at Clarkston Toll in Scotland, in October 1971, led to several changes and new developments in the ERS programme. X-ray scrutiny of the failed pipe revealed fissure corrosion, a form of stress corrosion cracking (SCC) not previously reported in the literature. For a time, this took the focus of attention of the corrosion team away from transmission pipeline stress corrosion cracking (SCC). Arthur Brown made a major contribution to the understanding and the means of control of SCC in both these areas; as he had already done in the case of reformer gas induced internal cracking of pipes.

Another outcome of the incident was the organising of Incident Investigation teams, although it was a later series of incidents at the end of 1976 that put the teams onto a more formal and permanent footing. Les Hinsley led this activity with great enthusiasm and flair. Nothing was ever too difficult nor was the time unacceptable - including Christmas Day!

Pipe location was not overlooked and ERS produced its own unique design (Gascopact) which was licensed out for manufacture. Unfortunately, it was not a commercial success as cheaper competitor products soon became available. It did, however, spur others to greater efforts and the outcome was of considerable benefit to the 'man in the field'. David Daniels and his manufacturing co-author, Arthur Blears, presented a Silver Medal winning paper on the topic to the IGE in November 1983. No existing system could locate plastic pipe, which was going into the ground in ever increasing quantities and David and his team turned their attention to finding a solution. Considerable fundamental and inspired study led to a 'downward looking' radar system, which was demonstrated as a 'world first' at the World Gas Conference in Washington DC in May 1988. Although the system proved to be only 90% efficient and was therefore not developed commercially for the originally intended purpose, ideas arising from the development have found numerous Parallel applications (including the location of long buried human bodies!).

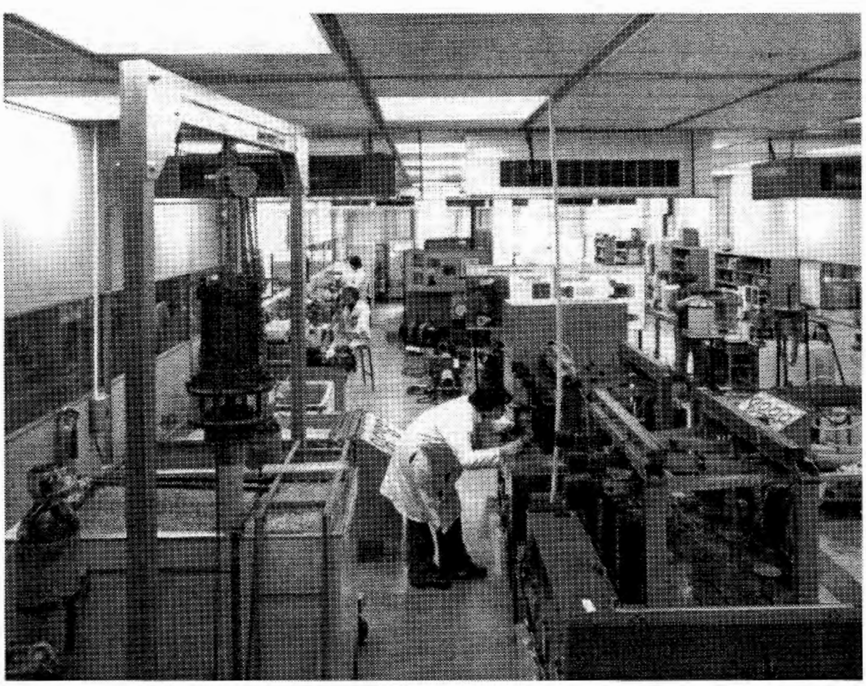


Fig. 15 Plastics Laboratory – located on the Ground Floor – Main Building – prior to being destroyed by a fire in 1987

The application of polyethylene (PE) to gas distribution is undoubtedly one of the premier success stories of the Gas Industry during the past 25 years (Fig.15). Pioneered in the USA, where it was cheaper than alternatives such as PVC then being investigated in Europe, PE was slowly gaining acceptance in that country. ERS played a leading role from the outset and produced the basic specifications for the tough, high integrity, materials that are widely utilised throughout the world today. Eventually, several companies set up manufacturing plant in the UK and ample supplies of pipe and fittings, covering a wide range of sizes, are now freely available. Lindsay Ewing and his team led the way with a comprehensive approach covering pipe properties, fittings design, jointing methods, field equipment design, and a whole range of inspection and test methods. The work continues to this day, producing further refinements including the introduction of improved automation into field operations and seeking and assessing new materials for more demanding applications.

Responding to requirements for reducing the labour intensive nature of pipe laying, ERS developed several new and highly productive field techniques and then played a strong part in encouraging their introduction into the Industry. They included narrow trenching, pavement sawing, improved reinstatement materials and methods, hydraulically operated tools, and optimised layout of tools and equipment in Distribution vehicles.

The late 70s saw a major drive into 'no-dig' methods for the repair and replacement of old mains and the laying of new ones. ERS participated in the development of several and again played a major role in encouraging their use throughout the Industry. Work was initiated on a guided mole in 1986, with feed-back signals from the below ground percussive head to a computer controlled guidance system on the surface. Rotamole is now in use throughout British Gas.

Returning to cast iron, a particularly successful development was Alec Carruther's 'Iris Stop' flow stopping equipment. This reduced the cost of carrying out live modifications to medium pressure mains (those working up to 2 bar) to the extent that, across the Industry, the savings in fittings alone exceeded the total cost of the ERS programme on distribution each and every year. This assessment, undertaken in the early 80s, did more to convince the Board Member for Finance of the value of R&D than any other single activity of the Station.

Last, but not least in this summary, comes the gas control module, conceived by Arthur Smelt and Derek Stoves in the late 70s. This was essentially a compact prepackaged governor installation which was factory assembled and tested before being placed in the field, usually in an environmentally friendly underground location. The story was set out in a paper by David Needham and Alan Spearman to the IGE in May 1985.

15. The British Gas School of Engineering

To be of value, all the activity had to be 'marketed' to Regional engineers and their staff. A special drive was mounted by David Needham in 1974. This involved a team of senior staff travelling around Regions giving talks and displaying samples of new and improved equipment. It became fondly known as 'Monty Needham's Flying Circus', in line with a popular, if less serious, TV programme of the time! This exercise did much to assist the case for the School of Engineering, against the competing demands for the construction of a substantial rig, at Killingworth, to test the performance of large transmission pipeline fittings. The potentially much greater added value of the school left no choice and construction was therefore authorised. The resounding success of the school over the years illuminates the correctness of the decision (Fig.16a and b).

Fig. 16a A Distribution Update Course in the ERS Lecture Theatre – prior to moving to the School of Engineering (circa 1975).

Left to Right – Bernard Heywood (NR), Dave Needham, Jack Peacock (NR), Harry Tishler, Colin Braithwaite, Dick West, Mike Jackman (LRS).

In designing the school, the opportunity was taken to enhance the laboratory space by constructing a combined training centre and ERS extension, connected to the main building by an overhead walkway. The building, designed once more by Ryder and Yates, is on two floors, the upper floor providing a lecture theatre to accommodate 125 delegates, an exhibition area, and enhanced catering facilities. These latter allowed the existing staff restaurant in the main building to be converted to additional, and badly needed, office accommodation. The ground floor provided all the basic facilities required by the training school.

The school opened in October 1977, and under its ex-army Manager, Gerry Davies, has paid its way handsomely ever since. A substantial number of courses are offered to Company personnel, covering topics ranging from offshore production to the customer's meter. Well over 1000 'students' pass through the school every year.

16. Management Changes, Comings and Goings

As the staffing levels increased during the late 1960s and early 1970s, so the management structure was also changed in order to optimise the development of the additional resources.

In 1969, Les Mercer was appointed Deputy to the Director and Gerry Clerehugh took over responsibility for a new division covering all work on materials. Gerry immediately took the initiative to push forward the establishment of PE as the standard distribution material. David Needham became responsible for all transmission projects and for setting up a new Engineering Science division. David Randall, a mathematician with strong statistical skills, was given responsibility for Distribution Design and Planning.

Somewhat later, in mid 1972, steps were taken to bring the management structure in line with the other Research Stations and to reflect the further growth of staff numbers. An additional level of management was introduced by the appointment of three Assistant Directors, with specific responsibility for technical disciplines and for project planning and control, and technology transfer out to the Industry. As such, this was the forerunner

Fig. 16b Dr. John Cunningham (Under Secretary of State for Energy) opening the School of Engineering 1977.

Denis Rooke (HEad of Production and Supply Division) in attendance.

of the present day matrix structure, albeit in a relatively less well defined format. Thus, Les Mercer served as deputy to the Director, head of High Pressure Technology projects, and was responsible for two technical divisions - Materials (Tom Harrison) and Transmission Engineering (Gerry Clerehugh). David Needham took his first steps towards the 'Mr Distribution' role as Head of Distribution and Low Pressure projects, as well as becoming responsible for three technical divisions - Development and Projects (Alan Spearman), Distribution Design (Mike Rouse) and Control and Instrumentation (John Newcombe). Brian Thompson, as the third Assistant Director, covered Administration through the Scientific Secretary (Mervin Piper) and Workshop and Site Services (Jim McCourt).

The interest in the development of on line inspection techniques for pipelines, which started in a small way in the late 60s, developed to such an extent in the early years of the 70s that it began to dominate the usage of facilities and resources at ERS. It became necessary to split the Transmission Engineering Division into two, with Gerald Clerehugh continuing to manage the on line inspection activities, while Derek James was appointed manager of a newly formed High Pressure Engineering Division. He held this position only briefly, before taking up a post in the Production & Supplies Division at Headquarters in 1975. He was succeeded by Dennis Neale, who had previously been recruited into ERS by Derek himself from the aircraft industry. In 1974, John Newcombe left ERS to join Vickers, at the same time that Mike Rouse resigned to join the Water Research Association. A new Systems Division was created under Harry Tishler and Mike Sporton was appointed Manager, Control & Instrumentation. This change enhanced the drive to electronics - a fact recognised in a change of name to Electronics & Instrumentation in 1977. As electronics penetrated into virtually every field of engineering, further changes were made in later years which distributed the rapidly growing skills in the topic into other, more traditionally-minded, Divisions.

In 1977 Brian Thompson left ERS to become Secretary to the North West Region of British Gas and Les Mercer had a brief spell covering Administration/Site Services. Later that year Les went on secondment with the Production & Supply Division in London, giving Tom Harrison a taste of Transmission Projects. In August 1977 Tom was, however, permanently appointed to the Assistant Director post vacated by Brian Thompson.

17. On-Line Inspection (OLI)

As mentioned above, the early stirrings of on-line inspection date back to the late 1960s. John van der Post had recognised that putting high quality pipe into the ground was only part of the drive to ensure maximum integrity and safety in gas transmission operations. As with all pressurised systems, in-service regular checking is essential to ensure continuing 'fitness for purpose'. Whilst this could be done by repeated high level pressure testing with water, the method was both inconvenient and expensive.

Inspection devices (intelligent pigs) had been developed and were in operation in the USA. These were brought over to the UK and subjected to rigorous testing, both in specially constructed test loops and in actual operational pipelines. ERS worked especially closely with the East Midlands Area Gas Board engineers, during this period, on many aspects of gas transportation technology. Of particular note was the pioneering and enthusiastic assistance of the Board's Chief Engineer, Cedric Brown, the, now, Chief Executive of British Gas plc. The American inspection pigs produced a far from convincing performance and, in line with John van der Post's 'four point plan' (see Part II), attempts were made to get the American operators to produce the necessary improvements. Even the offer of UK gas industry finance gained a lukewarm reception and so attention was turned to UK and continental European sources. Again, no fully

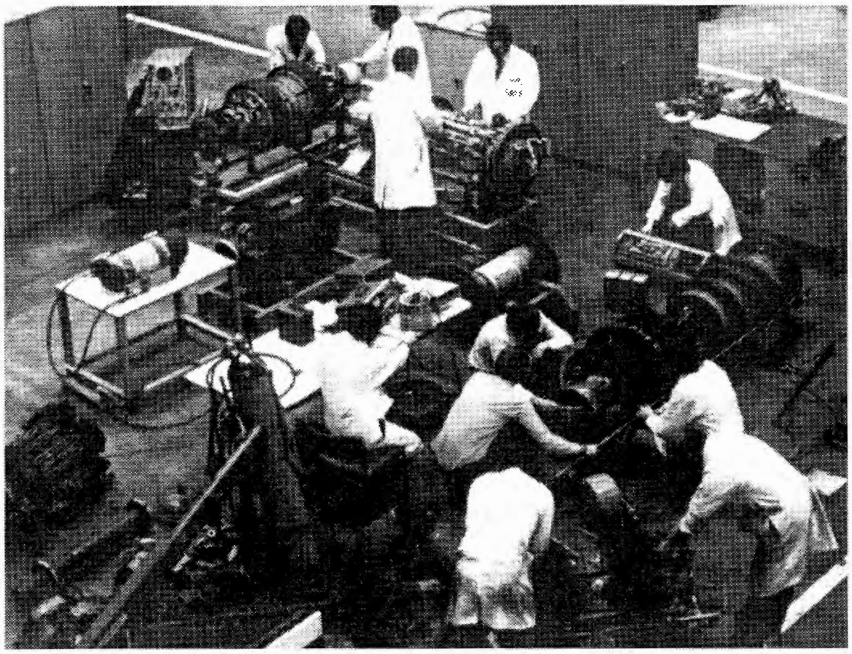


Fig. 17 Work on the Pig in the Crane Bay.

convincing offer came forward and it was with great courage and foresight that John van der Post put forward the case, and gained full approval, for an in-house intelligent pig development programme (Figs.17 and 18). From the outset he had a remarkably clear vision of the essential stages to success, in both technical and commercial terms. The ultimate achievement of a fully commercial world beating system was in his long term plan from the outset.

A detailed account of the progress of the On-Line Inspection project is given in Part III, so suffice it to say here that the importance of the project was judged to be such that, in May 1975, Gerry Clerehugh was promoted to Assistant Director (OLI), with Ernie Shannon as Division Manager.

18. Further Management Changes, Comings and Goings

Fig 18 Preparing for a Run at Low Thornley.

Left to Right – Joe Hodgson, Geoff Lowe, Jim Parry, George Redford, Bill Appleby, Ernie Shannon, Gerry Clerehugh, Rau Tailford and L:ewis Morgan.

A totally unexpected event was the departure of John van der Post to the water industry in February 1978. This resulted in the appointment of Les Mercer as his successor and David Needham as the deputising Director. At the same time, it was recognised that the On Line Inspection project had come of age and needed a separate existence in order to continue developing to best advantage. As a result, Gerry Clerehugh was elevated to Director status and, although OLI remained on the ERS site until the middle of 1979, the Cramlington site was acquired and adapted to the needs of the rapidly expanding team. More than 100 staff transferred to Cramlington, reducing the overall establishment remaining at Killingworth to fewer than 400.

Under Les Mercer's directorship, the next 10 years were a period of relative stability after the turbulent early years. The Directorate, then comprising Les Mercer, David Needham and Tom Harrison, was enhanced by the arrival of Nick Townsend, recruited from the British Steel Corporation, in October 1978. Nick was initially given responsibility for the Transmission and High Pressure Engineering work, and eventually also became responsible for developing the Station's major involvement in offshore technology.

During the early part of this new management era, a number of divisional managers were appointed from staff who already had a significant track record at the Research Station. Roy Wilkins took over responsibility for the Materials Division - a post which he held until he joined OLIC as Assistant Director in 1984. He was succeeded by Phil Kirkwood, who had been recruited several years previously as a welding expert from British Steel.

Brian Flood became Manager of a newly formed Pipeline Engineering Division, which brought together most of the large scale testing work and facilities, including Spadeadam, whilst Les Hinsley, well known for his 'Distribution Incident' work was appointed Manager of the Distribution Division.

In 1986, Mike Sporton, who had done so much to expand and develop the electronics & computing expertise within the Station, left to take up a post with Lucas Engineering. Following a minor reorganisation, Harry Tishler succeeded Mike, whilst Maurice Tallantyre took over Strategic Studies. Maurice was primarily responsible for the significant development of the computing infrastructure at ERS during the late 80s and early 90s.

19. Site Development

The trend, first seen in the 70s, for much of the ERS test programme to move out to specialised facilities changed the whole pattern of work at Killingworth. The valued and flexible crane-bay area (Fig.19), which served the laboratory so well in its early days, became less relevant for large scale assembly and testing, although it was adapted to several new, but less demanding, uses with the passage of time. Coupled with these changes were those occurring in the offices and some of the traditional laboratory areas. The sweeping influence of the personal computer (PC) in the 80s was the main factor here. Thus, much of the theoretical and modelling work is now done on networked PCs, whilst most of the large scale experimental work is undertaken away from the Killingworth site.

By the early 80s, the number of staff had grown to approximately 450 (386 after OLI departure) and more than 25% of staff and activities were housed in assorted temporary accommodation around the site, the major part of which had very limited planning permission. Numerous options for expanding the laboratory and office accommodation were considered - eventually the most cost effective solution was chosen, namely the extension of the main ERS building. In addition, the erection of a separate modular building to accommodate the Distribution Engineering work at ERS was also accepted.

Although these proposals were initially accepted, they did not proceed, because the newly appointed Chief Executive, Mr Robert Evans, withheld permission for all further Capital projects until an overall review of the Industry's requirements had taken place.

Fig 19 The Crane Bay in the Main Building 1974.

The problem of further accommodation was eventually solved in early 1986, when the former Government Skill Centre, adjacent to the Engineering Research Station, came on the market and was purchased. The Skill Centre comprised approximately 100,000sq.ft of accommodation on 5.5 acres, which had been built mainly in the early 70s and consisted essentially of two main factory units with substantial office and canteen facilities. This facility was considerably modified over the following years, finally being completed in 1993. The building modifications were master-minded by George Burdon and the first building to be completed was used to house distribution engineering work.

It is true to say that, without this addition to ERS it would not have been possible to expand and take onboard the additional work required of ERS in the late 80s and early 90s. In addition, the reorganisation which took place in 1989, when a further 86 staff were transferred from OLI at Cramlington to Killingworth, could not have taken place.

20. Notable Visitors and Events

As one of British Gas' show-places, ERS has, over the years, received many notable visitors and this account would not be complete without some reference to a number of these. Although Sir Denis Rooke visited ERS on many occasions, one particularly noteworthy visit took place in May 1987 when he was invited to open the newly converted Skill Centre building as part of the Silver Jubilee celebrations of ERS' arrival in the North East (Fig.20a and b, Fig.21). That event also brought together, for the last time, the four senior British Gas figures most influential in the early development of ERS, Sir Kenneth Hutchinson, Dr James Burns and Sir Denis Rook and Mr Leslie Clarke.

ERS SILVER JUBILEE – MAY 1987

Fig. 20a Dr Les Mercer welcomes distinguished visitors at lunch.

Left to Right – Geoffrey Roberts, Sir Henry Jones, Gerry Clerehugh, Les Mercer, Dr James Burns, Sir Kenneth Hutchinson.

Fig 20b ERS's Principal Patrons in conference.

Sir Denis Rooke, Dr James Burns, Leslie Clarke, Sir Kenneth Hutchinson.

Fig. 21 A group of "old hands" celebrating the Silver Jubilee.

Left to Right – Hughie Gilholme, Doug Whiteman, Dick Lowry, Tom Harrison, John Newcombe, Jim McCourt, Brian Thompson, Mervyn Piper, Les Mercer, Lila Buchanan, Peter Davies, Keith Richards, Eric Johnson, Derrick James, Brian Huggett, Gerry Clerehugh, Roy Wilkins.

Another outstanding occasion for many ERS staff was the visit in 1980 of the, then, Prime Minister Mrs (now Lady) Margaret Thatcher. At the time the Government was considering the construction of a North Sea pipeline gathering system and Sir Denis Rooke arranged the visit to ERS as part of a demonstration of British Gas expertise in pipeline technology. During her tour of ERS Mrs Thatcher's scientific training was evidenced by her well informed questioning and she gave every indication of enjoying the visit (Fig.22a and b).

Fig. 22a Visit of the Prime Minister – Margaret Thatcher 1987. With Denis Rooke, Dennis Thatcher and Alan Spearman.

Fig 22b The Prime Minister politely declines an invitation to the Xmas Show from the "Two Ronnies".

In April 1991 ERS was honoured to receive a visit from the Duke of Kent (Fig.23), who came at the personal invitation of Mr James McHugh, Managing Director, Western Regions NTS & Construction, (retired).

Fig. 23 The Duke of Kent visiting ERS in 1991. Enjoying a joke with Gerry Clerehugh, Maurice Tallantyre and James McHugh in attendance.

Three other special ERS 'family' events should also be mentioned here. Having attracted staff mainly from outside of British Gas, long service was not a normal feature of staff employment records. It was, therefore, not until ?? that two ERS staff, Dick Lowry and Bill Lunn, both with previous service in Northern Region, achieved the distinction of being the first at ERS to receive 25 year service awards (Fig.24). The second special event was the award in May 1981 to Stan Smith (driver extraordinaire and pillar of the Purchasing Section) of the British Empire Medal. He received this from the Lord Lieutenant of Northumberland at a ceremony held at ERS (Fig.25). Finally, Dick Lowry was awarded an MBE in the 1988 Queen's Birthday Honours List; he went to Buckingham Palace to receive his award.

Fig. 24 The first 25 year service award at ERS. To Dick Lowry and Bill Lunn (previously employed by Northern Gas Board).

21. Offshore Engineering

The 1980s ushered in a new and exciting phase of the Station's activities - offshore engineering. The first attempt to develop an offshore presence at ERS came long before the industry moved positively in that direction. This was in 1974, when Derek James began preliminary opportunity seeking studies. Little of real substance emerged and the topic was 'put on the back burner' until a rig operating in the English Channel suffered fractures in the drill conductor tube. Dennis Neale and his team produced a solution in 'double quick time' and this led to a revival of interest and positive support for ERS developing relevant expertise to serve the Company's growing involvement in natural gas exploration and production.

Fig. 25 Stan Smith with his wife after being presented with the BEM at ERS by the Lord Lieutenant in May 1981.

Soon after Nick Townsend arrived in 1978, he was given full responsibility for the topic. The manpower involved expanded rapidly from less than one man-year in 78/79 to seven in 80/81 and on to twentytwo in 83/84.

When E&P became particularly concerned about how quickly supplies from Morecambe Bay could be brought back on stream, following a hypothetical fracture of that pipeline, they turned to R&D to consider the technical ramifications of the apparently simple requirement of completing the repair in 21 days. Brian Flood and Nigel Wright headed up the response to this request and it rapidly became clear that then available technology was incapable of repairing the line in 21 days. A new approach had, therefore, to be introduced, and this led to the need for test facilities different from any previously available at ERS.

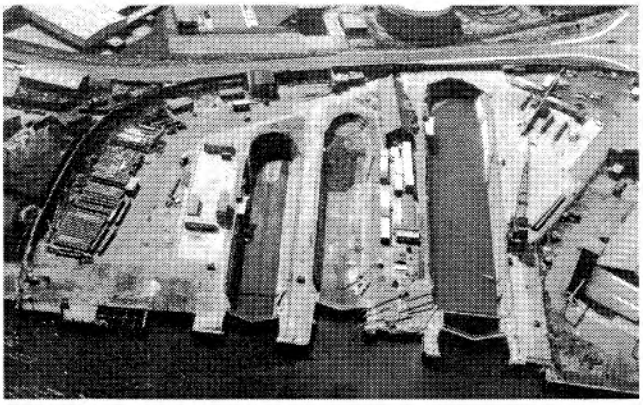


Fig. 26a Aerial View of the Dry Dock at Blyth. Converted by ERS into an Underwater Research Facility.

It then became a question of finding a suitable site close to Newcastle. When Eddy Beck discovered the three docks at Blyth the search was over. Blyth docks are a 10 mile journey from the Engineering Research Station at Killingworth, and are well served by a wide road system. The facilities at Blyth not only have three docks, but also privacy and a substantial amount of spare space around the docks on which preparation could be made and equipment stored (Fig.26a and b). Blyth Harbour Commission were very helpful to the developments from the outset.

With Eddy Beck looking after the site, Nigel Wright, using engineers and technicians from Killingworth, introduced the first trials to Blyth docks. Close co-operation was established with Exploration & Production staff, who gave advice about the safety of divers on the site and the need for decompression and other facilities, as well as general care and upkeep of such facilities.

The work started with tests to determine the most effective means for the removal of concrete weight coating from offshore pipelines and went on to the evaluation of mechanical couplings and of excavating equipment.

The Blyth Outstation then became involved in the assessment and development of repair methods for an offshore platform. British Gas engineers on the Rough platform were replacing some sections of riser support with strengthening members. The area of the platform under repair was mocked up at the foot of a dock at Blyth and the repair structure brought to the dock; divers fitted the structure dry to a mocked up platform. Within the first day sufficient modifications accrued to have saved the cost of the trial! When the divers were confident that they knew what they were being asked to do offshore, the dock was flooded and the divers then set about fixing the repair underwater. At this stage even more useful data was gathered about the efficacy of the epoxy endfittings. At the end of the trial the diving team and the strengthening equipment were loaded aboard the diver support vessel and the repair was completed on the platform with days to spare, at a much lower cost than was expected.

Fig. 26b Work on a Coffer Dam at Blyth Dock.

A further programme involved testing the emergency pipeline repair system. For this, it was necessary for a sea bed simulation to be constructed in the bottom of dock 3. This dock contained a 36in concrete weight coated pipe which was to be the subject of an emergency pipeline repair. The trial, which was carried out over several weeks, was conducted in the manner of a genuine offshore piece of work and was a great success. While the equipment failed to carry out the trial in accordance with the procedures that had been pre-written for it, the information gathered allowed E&P, together with the engineers from the Engineering Research Station to bring forward suggestions that enabled the whole project to progress to a satisfactory conclusion.

The Blyth site continued to develop over the next few years and a wide range of tests were carried out. These included the assessment of pipeline repair methods, the development and proving of a novel seabed mapping system, the testing of comprehensive underwater inspection systems and specialised diver training. A paper presented to the Research Committee in January 1983, revealed the broadening extent of ERS activities in offshore engineering and outlined substantial input in the areas of corrosion control, structural engineering, non-destructive testing, maintenance and repair.

Notwithstanding all this activity, the basic 'four point plan' approach was faithfully followed. Nothing was done that had been properly done before or, if it needed to be done, could be better done elsewhere. In this context, active links were forged with offshore interests in DTI, SERC, EEC and individual oil companies. Nick Townsend had never been so pressurised, and he responded magnificently and played the key role in putting ERS well and truly onto the offshore stage.

The activities at Blyth only amounted to one part of the story. In parallel, theoretical and experimental studies expanded at Killingworth, particularly in the structural, corrosion, mathematical and non-destructive testing areas. Work led by Geoff Fearnehough to assess the fracture behaviour of offshore pipelines containing mixed gases and condensates which can influence the fracture driving forces) assumed prominence and, for a time, dominated the attention of the Spadeadam team.

Finally, reference must be made to the full scale test carried out at Loch Linhe in Scotland, which called for the simulation of a most demanding combination of conditions. The test was completed successfully due to the unstinting commitment of Dennis Jude and his team.

22. The 'Shannon' Era and Recent Years

By the middle of the 80s, Gerald Clerehugh, who had succeeded John Gray as Director of the Research Division, was giving serious consideration to the type of organisation needed to meet the Industry's requirements in the 90s and beyond. The decision was eventually taken to concentrate the research activities on two sites; Engineering, based at ERS Killingworth and Gas Research, in the broader sense, at a new site which was eventually Loughborough. This involved closing the existing facilities at LRS, MRS and Watson House and establishing the On Line Inspection Centre as a commercial unit, with the OLI R&D function returning to ERS.

To manage these changes, two HQ Directors of Research were therefore appointed, Les Mercer for Gas Research at the new Centre and Ernest Shannon for Engineering at Killingworth. Thus, Les Mercer's direct involvement with ERS, which started in London in 1965, came to an end, whilst Ernest Shannon returned after 10 years at Cramlington.

The overall reorganisation of Engineering research involved the transfer of 50 posts from LRS and 86 from OLIC, to ERS. At LRS, of the staff involved in Maths & Computing and Distribution Engineering, only 11 chose to relocate to the North, including Clive Ringrose and Norman Revell, both senior managers, who were to make significant contributions in the future. Clive was eventually promoted to Divisional Manager, Maths & Computing, in 1992.

The 86 staff transferred from OLI included the Electronics Division, managed by Gordon Pickard and the Design Office, managed by Colin Braithwaite. Both had joined ERS in the 70s and were now returning with many colleagues who, similarly, had started their career with British Gas at Killingworth.

Ernest Shannon proved to be a tough, uncompromising, manager. He worked very hard, over long hours, with great attention to detail - and he expected others to do likewise. He proved to be very much a 'hands on' person, delegation was simply not his style. This combination of intelligence, determination and dedication, sometimes led him to be perceived as somewhat dictatorial - jokingly described by the staff as 'putting on his Ian Paisley collar'.

He arrived at Killingworth determined to adopt the method project management based on a matrix structure, which had been so successfully implemented at Cramlington. This involved a considerable change in the existing management structure and method of working; a change which was not universally popular, particularly with the 'old hands'. However, it did promote opportunities for career development for some staff and was timely in that it produced an organisation which was better geared to meet the requirements of the new, ever-changing, Company structure.

Dr Shannon's stay at ERS was relatively short, but extremely effective. He was seconded to Special Duties in London in 1990 and eventually took up a new post of Group Director of Development in 1991.

On his departure, Tom Harrison was appointed Acting Director for twelve months, before eventually being appointed General Manager, see below.

The matrix structure adopted at ERS prepared the way for a similar Division-wide structure, which came into final operation in 1992 with the closing of LRS and Watson House in London and the occupation of the new Research Centre at Loughborough.

Thus, a new organisation was introduced which fully integrated the activities of the R&T Division. Following this major upheaval, Tom Harrison was appointed General Manager at ERS, Nick Townsend was appointed Programme Controller for Exploration & Production work, Maurice Tallantyre a similar post for Gas Transport & Storage, while Phil Kirkwood became Technical Controller for Engineering Design. Nick, Maurice and Phil, whilst remaining located at ERS, had responsibilities encompassing the whole Division.

23. Conclusion

During its twentyfive plus years of service, ERS has touched on almost every field of engineering activity relevant to the interests of British Gas. Engineering research in areas other than process technology had a rather hesitant start in the Gas Industry. However, once the vision in the mind of Sir Kenneth Hutchinson had taken form, the vital critical mass quickly established itself under the inspired guidance of that remarkable visionary, John van der Post. John, and his initial team of ten, founded a Station which grew to well over 500 staff and led to the world beating OLI activity, itself employing over 300 staff. Last, but not least, the team provided a basic training ground for many whom were to move to senior positions within Research and Technology and throughout the Company. Those fortunate enough to have been involved, even if only for a small part, can be justifiably proud of the outcome.

Part 2 –

People who Influenced the Progress of the Station

1. Introduction

In the introduction to Part 1 reference was made to the fact that it is the people within who 'make or break' an enterprise such as ERS. The management and staff jointly develop an organisational ethos and it is upon their combined activities that the success or failure of the organisation critically depends. This part of the ERS history is, therefore, devoted to the people at ERS and how they have interacted with each other, and with their 'customers' throughout the Gas Industry. Regretfully, it becomes a monumental, if not impossible task to attempt to mention all the thousand or more people who have passed through the portals of ERS since its establishment in the mid-60s. Hence considerable selection has had to be done, involving, by its very nature, a substantial degree of subjective judgement. Those omitted from the story should not draw the conclusion that their contribution is any less valued. It is simply the old adage of 'the quart and the pint pot'.

In the early 70s, a Directorate team of four persons was set up within ERS. Led from the front by John van der Post, this had the task of determining policy and direction for the Station in line with overall Company policy. The key players at the specialist technical level were the Division Managers. They and their teams provided the vital basic skills which served the complex and wide ranging field of engineering appropriate to ERS' theatre of activity. At this same level, the Station developed comprehensive administrative and laboratory technical service functions as it progressively moved to a higher degree of self sufficiency, becoming more of an 'island' site, from the mid-70s onwards. Although the make-up of the Divisions changed from time to time in order better to meet the changing needs of the Industry, they offer a useful framework around which the individual people stories can be fashioned. This is the approach followed below which, it is hoped, will give a sense of continuity and consistency to the personal details which otherwise might appear as a rather fragmented and clinical catalogue.

The story is presented through the medium of three linked sections. The first deals with the Directorate team, whilst the second looks at the Division Managers. In passing it may be observed that an overview of the personnel in these two areas gives the impression of a minor 'Who's Who' in the aircraft and nuclear power industries. With the change of fortunes of the Gas Industry in the '60s and, in particular, the coming of natural gas, such an influx of 'high tech' engineers and scientists was indeed well timed and fortunate for the burgeoning Industry. The third and final section described the progress of some ERS alumni who moved on to other activities both within and outside the Industry. The prime purpose for its inclusion is to look at the role of ERS in preparing and introducing staff for senior operational posts within the Industry. Such transfers were a part of John van der Post's 'master plan' from the outset. He saw the value of a regular and healthy level of exchange in both directions - out of and into ERS. This would both aid technology transfer and encourage a favourable view towards, and enhance expectations from, the Station.

2. The Directorate

John Laurens van der Post (Director 1966-1978)

As emphasised in Part 1, John van der Post was a man of ideas and imagination. Coupled with his drive and determination, the conception, birth and progressive growth of ERS became virtually inevitable. At the outset, he was the Directorate; very much a 'one man band', although, being new to an old and long established Industry, he sought advice from all quarters and then acted with courage and flair.

John was the remarkable son of an even more remarkable father, Sir Laurens van der Post, and his premature death in 1984 at the age of 55, some six years after leaving the Gas Industry, was a tragic loss which deprived the Engineering profession of one of its brightest and most imaginative talents. John van der Post, who was born in 1928, was brought up and educated in South Africa, graduating in mechanical engineering from the University of Natal. He came to England in 1952, joining Rolls-Royce, Derby, as a graduate engineer, during which time he worked on the development of the Dart turbine engine. He then spent seven years with Atomic Power Constructions and played a prominent role in several leading edge reactor developments. As noted earlier, he came to the Gas Council in July 1964, with the task of creating an entirely new engineering presence. In order to gain the necessary freedom of action, he took the brave step away from London in 1966 to establish what was to become one of, if not the most, significant development in the history of gas engineering R&D world-wide at the time.

John van der Post's approach was based in equal measure on detailed and fundamental analysis and on practical commonsense. This is aptly demonstrated in his enunciation of the now famous 'Four Points' for project planning and/or problem solving, namely:

(i) Define the problem.
(ii) Seek what, if any, solutions exist and implement them.
(iii) If only incomplete solutions exist endeavour to have them completed, probably by whoever has already done the work so far.
(iv) If all else fails, develop your own solution.

The four points epitomise John, who was ever the practical engineer principally concerned that the results of the work undertaken at ERS should be translated into full and timely action in the field.

Being practical is a fairly common feature amongst engineers, but when, as in John van der Post's case, it goes along with creativity, that is a rare combination indeed. Descriptions of John usually abound with words such as imaginative, radical and intelligent, and tangible examples of his creative talent are not difficult to find.

So, for instance, Ted Nicklin, one of the architects responsible for the design of the ERS buildings, in describing how the requirements placed on the design were changed virtually overnight by the discovery of North Sea gas, comments:

'... nothing could have been more stimulating to new thinking than his willingness to think in radical and innovative ways about the design of the new accommodation ... '. The approach, encouraged and wholeheartedly supported by John van der Post, of total flexibility achieved by designing interchangeable office and laboratory facilities on a modular basis, with an internal partitioning system that could be taken down and re-erected in a new configuration, has served ERS extremely well and has met every requirement placed on it in the 25 years of its existence.

Another example was John's insistence that all personnel at ERS should be employed on staff conditions and that the unskilled / semiskilled employees should work to a highly flexible 'Handyman' job description. These measures avoided numerous employee relations problems arising both from concerns about bonus rates and from comparisons with manual employees' conditions in British Gas Northern. In a Company that may be gradually moving to harmonisation of conditions in the 1990's, it could be said that John was 25 years ahead of his time.

Turning from his managerial to his engineering achievements, one of John's most successful initiatives was the development of the intelligent pig. He was quick to recognise the need for a comprehensive inspection system to ensure the safe and economic use of one of the Company's major assets, its many thousands of miles of buried pipeline. Having recognised the need, it was typical of John to have the couraqe of his convictions and to make sufficient technical expertise, facilities and finances available for this concept to be transformed into reality.

While John's intellect and abilities earned universal respect, his personal relationships with other people were at times far from smooth. This was particularly true of his relations with British Gas HQ and with Trade Union representatives. As already mentioned, he was fortunate in having a highly skilled negotiator and administrative entrepreneur, Brian Thompson, who could be relied upon to defuse many potentially explosive situations.

On a personal level John can perhaps best be described as a 'loner'. In social situations he was almost wholly lacking in small talk and would only take a real interest if the discussion concerned a concept or issue. Similarly, he was not interested in team sports but was an enthusiastic private pilot, having bought a part-share in an aeroplane. Given his propensity to innovate, it is not surprising that he attempted to arrange a mileage rate for his business flights. He contended that his flying saved the Company a great deal of his time. Even Brian Thompson's persuasive powers were not sufficient on that occasion though.

It is only possible to speculate on the factors that influenced John's highly original but complex persona. Genetic factors undoubtedly played a role, as did his somewhat patrician upbringing in South Africa. This may have been why he sometimes came across as aloof and detached, despite the fact that he sought to run ERS on egalitarian principles. (For example, at John's insistence, ERS has always had single status dining facilities). While John was extremely proud of his father, he was also keen to impress him, probably a contributory factor to John's strong sense of ambition.

The really successful manager can be recognised by the legacy he, or she, leaves behind in terms of able, effective and promotable staff. On that criterion again John can be judged as highly successful, as many of the most senior levels of the R&T Division are filled with people recruited and developed by John van der Post.

In 1978, having served British Gas for 13 years, John felt that the challenges were no longer sufficient for his ever inquisitive intellect and so he moved on to take up a position as Chief Executive of the Water Research Centre. Again, he found himself in his element in this new role. The organisation was moribund and John's insight, drive and determination once again came to the fore. As a result, he left behind a further triumph in a reborn and widely envied organisation. But that is another story to be told elsewhere.

William Leslie (Les) Mercer (Director 1978-1988)

Dr Les Mercer was the second Director of ERS, taking over the reins from John van der Post early in 1978. John's departure ended an association which had begun some years before either of them joined British Gas and came about as the result of the merger of the nuclear power consortia, for which they were at that time working (GEC in Les' case and APC in John's).

When John joined British Gas he soon realised that British Gas was lacking in expertise in the field of materials technology. Based on their prior acquaintance, Les Mercer was, therefore, one of the first people John van der Post recruited to his new engineering team. Les had graduated from Leeds University with an honours degree in chemistry and a PhD in metallurgy, and had then spent 10 years working on advanced nuclear fuel materials. He consequently brought with him a wealth of experience in materials technology.

The two rapidly formed a highly successful team, with Les acting as John's deputy virtually right from the outset. The success of their association can, to some extent, be ascribed to the fact that their styles complemented each other. As noted earlier, John van der Post saw the provision of advice and assistance to the Industry's engineers as one of the major functions of ERS. This proved to be an activity tailor made for Les, who quickly established himself as the external face of ERS, becoming well known to the senior engineers within the Industry. Initially he concerned himself with problems arising from failures of steam naphtha reforming plant, but as the technology changed, so his remit became ever wider, building and maintaining a complex network of links between ERS and its clients.

His communicative skills were, however, not restricted to external contacts, but were also put to very good use internally, especially during his 10 years as Director. An innovation introduced by Les was his 'Christmas Lecture', in which he outlined the achievements of the past year and gave staff an indication of the Station's plans for the coming year. Despite the Station's evident successes during Les' period as Director, his frequent absences from ERS often drew comment in the Christmas pantomime and on one occasion it was suggested that he should sign the visitors' book on arrival at ERS!

No-one can have contact with Les without being infected by his energy, optimism and enthusiasm, all of which had a strong influence on the rapid growth of ERS in the late 1960s and early 70s. Following the switch from production technology in 1967, Les played a leading role in co-ordinating the Station's transmission programme, making significant contributions to the establishment of the Industry's pipeline specifications and safety standards.

He was also quick to recognise the growing importance of electronics and computing and, after becoming Director in 1978, made sure that ERS was at the forefront of such developments. Indeed, in 1980, jointly with Mike Sporton, he co-authored 'Microelectronics Serving Engineering', which was the first ever paper on digital electronics and its applications presented to the Institution of Gas Engineers.

Les Mercer has always taken an active role in the affairs of local, national and international professional bodies. In that respect he achieved an extraordinary feat by being elected as President of two major engineering bodies; the Institution of Gas Engineers in 1984/85 and the Institute of Metals in 1990/92. In the case of the latter, he was re-elected for a second year of office to oversee the crucial merger of the Institute of Metals with the Institute of Ceramics and the Rubber and Plastics Institute to become the Institute of Materials.

Les Mercer's other professional activities include serving six years on the Council of the International Gas Union and working in support of the Science and Engineering Research Council. He has also always had a strong interest in scientific and technological education and was the President of the North East Branch of the Association for Science Education, as well as working in support of the British Association for the Advancement of Science and being Visiting Professor at the University of Newcastle upon Tyne. His contribution to the Engineering profession was recognised in 1985 when he was elected to the Royal Academy (then Fellowship) of Engineering.

In 1988 change was once more in the air within British Gas. Privatisation was by then affecting all functions and R&D was no exception. As part of a wideranging reorganisation of R&D, Les was asked to 'pull up the roots' he and his family had put down in the North East of England and move to the Midlands as HQ Director, Gas Research. This gave him responsibility for the three Southern research stations (MRS, LRS and Watson House) and for developing the plan to establish a new site to bring these three together as a single unit. After 22 years in the North East, including 10 years as Director of ERS, this was not an easy step to take. However, the challenge beckoned and the customary enthusiasm soon took over. Having settled in Solihull and established his temporary office at MRS, he oversaw the successful amalgamation of the staff and their occupation of the new Gas Research Centre at Loughborough, before retiring from British Gas in November 1993. Both he and his wife found the Midlands very much to their liking. In this new environment, and with more time available than hitherto, Les continues to follow many old, and several new, interests.

Robert William Ernest (Ernie) Shannon (Director 1989-91)

As part of the new arrangements within R&D which took Les Mercer away from ERS in 1988, a new post of HQ Director, Engineering Research, was created. This replaced the previous Station Director position at ERS, although it involved similar duties, albeit with an enhanced range of activities. Dr Ernie Shannon relinquished his post as Director of the On Line Inspection Centre to return to ERS in this new position, after an absence of some 10 years.

Ernie Shannon had initially entered the Gas Industry by a unique route. During the late 1960s, the work on pipeline fracture control was accelerating and John van der Post was anxious to inject a larger measure of theoretical/conceptual input. Professor Alan Wells, head of the Department of Civil Engineering at the Queen's University of Belfast, and an international authority on fracture, was contracted to provide this input. It was through Professor Wells' good offices that Ernie, who at that time was working as a Lecturer in the Mechanical Engineering Department of the same University, was appointed to undertake the ERS work. The arrangement was that, although Ernie was appointed as a member of ERS staff, he would remain in Belfast to carry out the work under the overall guidance of Professor Wells.

Two years later, in 1972, it was decided to bring all the work together at Killingworth and Ernie moved his family and home to the north east of England. He brought with him a car registered in the Province, which caused a degree of consternation when a passing sharp-eyed policeman saw the vehicle in the ERS car park and, fearing the worst, raised the alarm! A more ironic situation was Ernie undertaking pipe fracture experiments (albeit models) causing what amounted to small explosions in the middle of Belfast!

Right from the outset it was recognised that Ernie Shannon was an extremely capable engineer. He advanced the theoretical treatment of the pipeline fracture process during his early years at Killingworth and played a key role in establishing a practical set of rules for operational use. At the same time, the on line inspection project was gathering momentum and, in 1974, Ernie was appointed Assistant Divisional Manager, with wide-ranging responsibilities within the project. One year later he was appointed Division Manager and he transferred to the new base at Cramlington when the project became free-standing and administratively separate from ERS, in 1978. Following Gerry Clerehugh's appointment as Director of Research, Ernie was further promoted to become Director of the On Line Inspection Centre.

As indicated, Ernie Shannon's involvement with ERS had, however, not come to an end. Quite apart from the close working relationship between the two Stations during the ten years following the move to Cramlington, particularly in the area of fracture mechanics associated with pipeline defect sensing, Ernie once again did something unique by returning to ERS in 1989 and serving in the role of HQ Director of Engineering Research for two years, although he departed from ERS in 1990 to take up special duties in London. Ernie eventually left the R&D Division in 1991 to take up a new London-based post as Group Director of Development.

During his second period at ERS, Ernie Shannon prepared the ground locally for the new division-wide matrix structure, which came into full operation in 1992 with the occupation of the new research centre at Loughborough. Although many changes had to be made to the approach followed at ERS, staff familiarisation with the concept helped its ultimate and universal adoption throughout the R&T Division.

Ernie Shannon is a tough, uncompromising, manager. He works very hard, over long hours and with great attention to detail, and he expects others to do likewise. He is also very much a 'hands-on' person, delegation is simply not his style. This combination of great intelligence, determination and dedication sometimes leads him to be perceived as somewhat 'dictatorial', jokingly described by his staff as 'putting his Ian Paisley collar on'. However, his considerable achievements, both at On Line Inspection and during both his spells at ERS. are widely recognised.

James Thomas (Tom) Harrison (Acting Director 1990-91 and then General Manager 1991-1993)

Tom Harrison was the fourth person to occupy the Director's chair at ERS. At the outset he served in the capacity of Acting Director on the departure of Ernie Shannon to London in 1990. Following the introduction of a full matrix management system across the whole of R&D in 1991, he was appointed General Manager, ERS; a very different post from that of the past, but nonetheless demanding in its own particular way.

Tom Harrison was a member of the team which came to the North East from London and, over the years, as the original team gradually dispersed, Tom became the one remaining member at ERS. An era thus truly came to an end when Tom retired from British Gas at the end of 1993.

Tom joined Les Mercer's Materials Group in 1966 to lead studies associated with corrosion and its control. From the start Tom's approach to research was both practical and methodical, always striving to establish a scientific basis, using the newest technology available, to gain an insight into the corrosion process. With the many corrosion problems facing the Industry, the demands on the corrosion team grew rapidly. Initially the team was concerned with steam naphtha reforming problems, but, from the late 1960's onwards, their focus was redirected entirely to studies of corrosion in the underground environment.

Tom led from the front, pursuing a number of parallel investigations which were mainly concerned with coatings technology and the search for a mechanism of stress corrosion cracking in carbon manganese steels. Tom and his team were successful in both respects, in the one instance developing a thin film epoxy coating which soon became established as the standard for national transmission pipelines and in the other, developing an empirical relationship which aided in the selection of appropriate corrosion control measures for British Gas pipelines.

Following the Clarkston Toll incident, Tom and his team played a leading role in discovering and explaining fissure corrosion in grey and ductile cast iron. Fortunately, by this time polyethylene had come on to the scene and Tom, building on foundations laid by Gerry Clerehugh, turned the attentions of some of his team to comprehensive studies of this material as a long term choice for low pressure distribution systems.

Tom's career took a major change of direction when he was asked to take responsibility for administrative and engineering services at ERS. He responded with great vigour and quickly established himself as a tough, but fair, leader of the largest team on the Station, made up of a mix of engineers, technicians and administrative staff. Tom became a regular feature in the Christmas pantomime programme and, in one classic, was portrayed as 'J.T.' of Darras in a take-off of 'J.R.' of 'Dallas'. (Darras Hall being the suburb of Newcastle in which Tom lives). The implications, considering J.R.'s reputation, were based on Tom's direct and no-nonsense approach to running his Division.

As already indicated, Tom became Acting Station Director in 1991 and General Manager, ERS, in 1992. His wide experience, covering many different roles, provided a solid foundation for these new positions and his influence spread beyond the immediate boundaries of ERS to the wider benefit of the R&T Division as a whole.

Throughout his life Tom has been, and indeed remains, a keen and talented sportsman. As a Yorkshireman he takes his cricket seriously, but recently golf has also come to the fore. Tom has also always played an active role as a professional engineer in institutional matters. Following several years serving on the committee of the North of England Section of the Institution of Gas Engineers, he was honoured by being elected Chairman for the 1992/1993 session.

Philip Robert Kirkwood (Acting Assistant Director 1990-92, Technical Controller 1991-)

The retirement of Tom Harrison ushers in the final stage of the story of the ERS Director's post. As part of the further rationalisation of R&D, overall responsibility for all facilities, covering both the Gas Research Centre (GRC) and ERS, including the Outstations, was placed with Lawrence Conway, hitherto General Manager, GRC. However, local responsibility was shared with Philip Kirkwood, Technical Controller, Engineering Design.

Phil arrived at ERS in March 1980 to take up an appointment as Assistant Divisional Manager, responsible for welding, metallurgy, NDT and mechanical testing. Educated in Scotland, he had taken an external London degree in engineering metallurgy and had then spent twelve years within the steel industry specialising in fracture mechanics and welding of engineering structures. During this time he spent a year living and working in Rio de Janeiro, Brazil.

In the late 1970s Phil completed research work on a new submerged arc welding wire and for this he was awarded a PhD. Additionally he received the Welding Institute's Sir William James Larke Gold Medal and the Leslie Lidstone Esab Gold Medal for his contribution to the science and practice of welding.

Phil's appointment to ERS came at an ideal time strategically, since he introduced deep understanding of off-shore structural steels and their fabrication at a time when the E&P programme was just starting to take off. This soon enabled ERS to make a unique contribution to the problems encountered during the fabrication of the Hutton Tension Leg platform at Nigg Bay, saving British Gas and its partners several million pounds. It incidentally also led to a revision of the British Standard guidance document relating to the welding of structural steels.

In 1984, when Roy Wilkins left to go to OLIC, Phil was promoted to Manager of the Materials Division. Subsequently, in 1990, he was promoted again to Acting Assistant Director, responsible for administration, a post which he held until 1991 when the R&T Division was restructured.

Phil is currently Technical Controller, Engineering Design, a post which involves the management of 160 staff, some based at ERS and some at Loughborough.

Away from work, Phil is an active member of his local parish council, and relaxes by playing golf, gardening and hill walking.

Brian Thompson (Assistant Director, ERS 1972-1977)

Brian joined John van der Post's team in 1966, just before the London-based technical staff moved North. He came with a wealth of experience gained as an accountant with several local Tyneside companies and eleven years in Uganda as an accountant with HM Overseas Civil Service. He played an invaluable role in preparing the ground for the new team and ensuring that it was professionally administered and properly cared for in subsequent years.

While many of the early developments at ERS were based on John van der Post's concepts, it was Brian Thompson's entrepreneurial skills that often transformed the concepts into reality. So when, for example, John became concerned about the lack of communications between sections within ERS, it was Brian who arranged for the suite of separate offices on the first floor of the building to be reconstructed as an open plan office. This rearrangement was not universally welcomed and it needed Brian's considerable skills in advocacy and negotiation to 'sell' the proposal to the staff concerned.

It was indeed in these areas of inter-personal skills and administration that Brian excelled. His approach was very much hands-on, as evidenced by his regular daily post-lunch tour of the site. Any irregularity or problem that was spotted during the tour would then become the subject of a missive, written in red ink, to the appropriate member of his staff.

Brian had tremendous drive and demanded much, both of himself and of his staff. However, in his dealings with people there was a rich vein of humour, which frequently won people over no matter how outrageous his expectations seemed. Brian's energy also found expression in his enjoyment of life. He was the enthusiastic owner of a series of expensive and powerful cars and above all, supported by his wife, Pat, he was a stylish and generous host. Thus, although Brian expected much from his staff, they found him fun to work with and held him in great affection and respect.

As the first Newcastle-based recruit to ERS, Brian was faced with a situation where there were no pre-existing administrative procedures. Far from being daunted by the prospect, Brian set to and developed innovative and effective systems that have stood the test of time and continue to serve ERS to this day. His talents were clearly also more widely recognised, as he became the first Chairman of the R&D Common Administrative Procedures Working Party. It is in this respect that Brian made his most valuable contribution, not only to the development of ERS, but also, more generally, to the whole of the R&D Division.

Following the excitements of the first 10 formative years, Brian was ready for fresh challenges. In 1977 he was appointed Regional Secretary of British Gas North Western, a post in which he remained until his retirement in 1990.

"A Walk aling The Wall" – DEC visit to ERS 1973.
Distinguished visitors include Bob Evans (far left) and Ron Gibbon (centre)

David Needham (Assistant Director, ERS 1971-92)

John van der Post recruited David Needham from the aircraft industry in 1967. He came from Hawker Siddeley Aviation at Brough in Yorkshire, where he had been Head of the Structures Department responsible for some 500 staff (including, for a very short time, Gerry Clerehugh). What David Needham, therefore, brought to ERS was a wealth of engineering and managerial experience. Additionally, he had considerable experience in dealing with the competing demands of Government departments, which he used to great advantage in the 1970s, mediating between Regions, or between Regions and HQ, on their often disparate views concerning Distribution engineering issues.

It was, however, following his appointment in 1972 as Assistant Director responsible for Distribution and Control and Instrumentation Systems, that David made his most valuable contributions. He was quick to realise that, founded as it was on largely 19th or early 20th century technology, Distribution engineering was fertile ground for innovation. Taking advantage of the impetus given to developments in Distribution engineering by the Clarkston Toll incident, he launched his team into a range of innovative projects, showing great skill in identifying and then pushing through the more promising developments. The GascoSeeker, Polyethylene systems and the Governor Module are outstanding examples of David's talent at backing 'winners'.

It was also at David's instigation that the Distribution Incident Team was established after Clarkston Toll, in 1971. As will be described in more detail in Part 3, the team has attended more than 200 incidents in the intervening years.

David was also a highly articulate advocate of the work being done at ERS. Acting as R&D's 'Mr Distribution', he made major contributions to those of the Company's senior committees which deal with Distribution, most notably to the Distribution Engineers' Committee. Additionally, following a suggestion from, the then, Mr Denis Rooke, David established a team in the mid-1970s to travel to the Regions to present the latest technology coming from ERS. As described elsewhere, this team's activities played a significant part in the eventual decision to establish the British Gas School of Engineering.

David contributed to a number of IGE papers, including 'Why Pipes Fail', written in collaboration with Malcolm Howe, which was presented to the 1979 Autumn meeting of the IGE, and won the IGE Gold Medal.

No description of David Needham would be complete without reference to his passion for golf. He made sure that the annual meeting of the DEC held at ERS would include a field visit, the site of which varied, but invariably included 18 very small excavations in a rural area!

Sadly, David's career was brought to a slightly premature close by ill health, which forced him to retire on his 64th birthday. It is typical of the man, however, that when he was offered the editorship of the present ERS History, he would have nothing of it, preferring to look forwards rather than backwards.

Nicholas (Nick) Arthur Townsend (Assistant Director, ERS 1978-1992, Programme Controller 1992-)

Nick qualified as a mechanical engineer and gained experience in civil nuclear power, aerospace and steel manufacturing plant. He came to ERS in October 1978, to the vacant post created by Les Mercer's promotion to Station Director earlier that year. In this respect, Nick was a 'rare bird', a senior appointment to ERS at a later stage in its development. He responded to an open advertisement along with several other highly qualified engineers. He arrived with little knowledge of the Gas Industry, but, with hard work and great determination, quickly found his feet and established himself both within the Station and with operational engineers out in the field. He brought new thinking into ERS and had a beneficial influence not only on those reporting to him, but on the whole of the senior management team.

Nick's appointment as Assistant Director coupled project responsibilities for Transmission Engineering with discipline or resource responsibilities for engineering sciences, experimental engineering and materials technology. In this way, with the early matrix structure operated at ERS, he was able to exercise a wide-ranging influence from the outset. Transmission Engineering matters took up much of Nick's time during the first few years and, as a member of the Transmission Engineers' Committee, he played a key role in keeping a vital part of the Station's programme in line with the needs of the Industry.

He also took on full responsibility for maintaining and developing the long established close working link with the Pipeline Research Committee in the USA. He became deeply involved in the growing international programmes on pipeline fracture testing and assessment and it was during this period that the specialised facilities at Spadeadam were built up to the world-leading position that they hold today.

However, the one very special area that Nick can call his own is that of offshore engineering. He picked up the early, rather abortive, attempts to establish ERS in this area and created an impressive presence and capability in the associated technology. Nick gave a lot of attention to establishing sound working links with 'end-user' personnel not an easy task considering that the area was new to the Company and many of the planning and operational engineers came in from oil companies and the like, with strongly held pre-existing views on most things, including technology! Nick was not to be deterred; he battled on and put ERS on the offshore technology map.

As time went by, the Transmission programme decreased and the staff skills were 'tuned' to the offshore area - an achievement that bears great credit to Nick's drive and determination. During the financial year 1978/79, when Nick arrived at ERS, the total offshore engineering effort was less than one man year. By 1983/84, it had grown to twentytwo.

Nick Townsend is a hard working, extremely capable and knowledgeable engineer. Furthermore, he demands the same level of performance from his staff and expects them to conform to his own high standards. He has exceptional skills as a writer and speaker, although some would observe that his application of the latter can, on occasion, be excessive! But, especially on matters engineering, it is all worth careful attention. All this takes time and Nick never tires of reminding his colleagues how short he is of it! More often than not, he is surrounded by a 'sea of paper' and he has also established a reputation for carrying around a large, usually over-filled, brief case.

Since joining ERS, Nick has developed his skills in one activity that had lain fallow for some time. His golfing capabilities improved under the critical, and at times devious, eye of David Needham, until he was able to maintain the honour of the Station, if not the country, on appropriate occasions in both the US and the UK. The other great love of his youth, organising and participating in motor sports activities, was perhaps wisely put aside. Maybe it is a hang-over from that period, but Nick is never more at home than behind the wheel of a fast saloon car with an open road before him. As with his professional activities, he is a model of competency in this role. Unfortunately, the arm of the law sees things differently and Nick has, on the odd occasion, had a brush with this area of authority!

The arrival of Nick Townsend at ERS was an important point in the history and development of the Station. His approach, his drive and determination, his professionalism, have all set standards for others to follow.

Maurice Tallantyre (Assistant Director, ERS 1991, Programme Controller 1992-)

Maurice is one of the few 'locals' to join the ranks of the senior management at ERS. He was born and educated in rural Northumberland and, after a relatively short sojourn in the south, studying aeronautical engineering at Queen Mary College, London, and then working in the aircraft industry, he returned to the North East in 1971 when he joined the Mathematics Group to work on the Control Advisory Programme (CAP) for transmission.

To describe Maurice as a 'Geordie' would, however, be misleading as he could not be so identified, either by speech nor by interests. Indeed his interests cover an extraordinarily wide spectrum, ranging from all aspects of engineering to the arts and from business organisation to philosophy. It would, therefore, probably be more accurate to describe Maurice as an 'intellectual', although this must not be taken to imply impracticality, which is far from the case.

Reference to his career progression shows a story of continual success which, with a characteristic mixture of modesty and humour, he attributes to two factors, firstly coming under the mentorship of Mike Rouse and later of David Needham and secondly discovering the availability of cheap suits! It was Mike Rouse who helped him make the transition in image from 'hippy' to responsible engineering professional, while David Needham introduced Maurice to non-desktop engineering.

Following a period in the Mathematics Group, Maurice spent two formative years working with Brian Bennett-Cowell on the design and construction of the Bishop Auckland test facility. However, in 1981 he returned to the Mathematics and Computing Group as Assistant Divisional Manager reporting to Harry Tishler. After Harry moved to take over the vacancy created by Mike Sporton's departure, Maurice took over responsibility for the whole of the Strategic Studies Division, reporting to David Needham.

It was during this time that he influenced and encouraged the widespread introduction of IT systems, both at ERS and more generally throughout British Gas. A paper, written jointly with Mike Bakowski of the East Midlands Region, on 'Developments in District Office Computing', presented in Cardiff to the 1988 Annual Meeting of the IGE, brought recognition for his pioneering work in the form of the Institution's Gold Medal. It is also probable that the paper had a significant influence in directing the Company's attention to the importance of Company Field Systems.

Maurice is clearly another one of the winners so ably spotted and backed by David Needham. As their association developed Maurice gradually acquired the mantle as David's right hand man and so in 1990, when illness forced David to retire, it was quite natural for Maurice to take over as Assistant Director. Shortly afterwards, however, the R&T reorganisation resulted in Maurice taking on a further change in responsibilities to become a Programme Controller.

Maurice's present appointment fits particularly well with another of his talents, namely his gift for public speaking. He has the ability to put over complex technical matters in simple terms which can be understood by non-specialists, which is all the more impressive since he rarely uses notes. As a result, he is in considerable demand as a speaker at IGE and other professional engineers' meetings.

Finally Maurice's enthusiasm for playing cricket must be mentioned and it is typical of his self-deprecating style that he describes himself as the most talented cricketer never to score a run or take a wicket for ERS.

Gerald Clerehugh (Assistant Director. ERS 1975-78)

Gerry Clerehugh, now the Head of Research & Technology for the whole of British Gas, came to ERS from the Hawker Siddeley Company, as had David Needham only a few months earlier. He was, however, no stranger to the North East of England, having spent three years at Durham University taking a Degree in Mathematics. During his subsequent years in the aerospace industry, he acquired a deep understanding of structures and aerodynamics, which was to greatly influence his contribution to British Gas, especially during his early career at ERS.

From the outset Gerry became involved in high pressure technology, helping to lay many of the foundations for a flourishing high pressure gas transmission programme. The late 1960s were also the period when some of the early ideas began to take root which eventually blossomed in the form of a world leading on-line inspection system. John van der Post played the leading role at that time, taking a direct and deep involvement in the topic. Gerry's contribution, in the main, came later when the project became 'free-standing', first towards the end of John's time in the Gas Industry, but, more significantly, when the project physically separated from ERS and established itself at a new site in Cramlington.

In 1969, as part of John van der Post's strategy of developing promising young engineers, Gerry was appointed Manager of a newly created Materials Division. No-one could have been more surprised than Gerry himself over this appointment; he has commented on many occasions since, that at that stage, he had little or no familiarity with that branch of technology. Gerry, always a quick learner, was soon making significant contributions and none more so than in his immediate and strong support for the development of PE as an alternative to cast iron for gas distribution mains. Some pioneering work in the South Eastern Gas Board had led to a series of trials utilising PVC pipes. These proved unsuccessful, largely because certain constituents of the manufactured gas, being distributed at the time, adversely influenced the pipe material. Picking up experience from th USA, Gerry and his team played a key role in establishing an alternative approach based on polyethylene. This included setting up laboratory facilities to study the behaviour of the material, establishing close and effective links with overseas expertise and taking the initiative to prepare the Industry to accept the new material, including the drafting of outline specifications.

In 1972 Gerry returned to wider ranging engineering activities in the role of Manager of the Transmission Engineering Division. The work encompassed studies in the areas of design, construction, safety and maintenance of high pressure gas transmission systems. In this new capacity he became responsible for the pipeline fracture studies programme. The initial attempts at assembling a theoretical approach to the topic were made at this time and he, therefore, made a significant contribution, along with many others, to the preliminary thoughts that led to revised pipeline codes, recommendations and standards, including IGE/TD/1.

His new responsibilities also included on-line inspection matters, which at that time were still very much at the embryo stage. During this period the main aim was to 'persuade' external specialist organisations, already involved in the topic, to develop their technology and to extend their activities to meet the more demanding requirements of the UK Gas Industry. Gerry Clerehugh, aided and abetted by John van der Post and Les Mercer, played a vital role in setting out these needs in a well founded and quantitative format.

The decision was eventually taken to handle the development in-house, as external organisations had shown little or no interest in 'running with the technology'. The financial commitment was growing and it became necessary to take special measures to safeguard the integrity and output of the project. Accordingly, a dedicated and secure area was provided within the ERS main building for the purpose. By May 1975 the OLI work had grown in importance to such an extent that it became necessary to adjust the management structure. Gerry was thus appointed Assistant Director, with dedicated and full responsibility for on-line inspection activities at ERS. The new situation suited Gerry's preferred style of 'holding the cards close to his chest'. Additionally, on John van der Post's express instructions, anything to do with on-line inspection was given top priority. This combination of circumstances was clearly not helpful to harmonious relations within ERS.

During the same period a further decision was taken to launch an even bolder project aimed at finding and interrogating cracked welds and, later, stress corrosion cracking in operating high pressure pipelines. It was recognised from the outset that the in-house team could not handle the additional load, nor did they have the demanding expertise needed for the task. It was decided to contract the work out to the Harwell laboratories of the Atomic Energy Authority. Gerry knew exactly what was wanted and it was not the existing NDT expertise long established at Harwell. What he wanted, and he would not deviate from this, was the very best team of physicists that could be brought together so that new and truly original thinking could be applied to the challenge. His persistence paid off and the project was brought to a successful conclusion some years later. It was the largest external piece of work ever tackled by Harwell and demanded a great deal of Gerry's personal attention throughout. His determination and refusal to be diverted from the path he had set, played a vital part in the ultimate success. This was all the more remarkable, considering the grave doubts being freely expressed by others at ERS that the task was beyond the limits of known technology.

The handling of the Harwell contract provides an excellent illustration of Gerry Clerehugh's character. As a true and dedicated Yorkshireman, he knows exactly what he wants and 'by heck' means to get it. This is not to say he is inflexible and, as a project or activity progresses, he will take changes in his stride if it becomes advantageous to do so.

By 1978 the On Line Inspection project had outgrown the facilities available at ERS and the decision was taken to relocate Gerry and his team in a separate purpose-built facility at Cramlington in Northumberland. At the same time, Gerry was promoted to the position of Director of the On Line Inspection Centre. The project came to fruition at Cramlington and an account of this would form a separate and fascinating story, of which British Gas could be justly proud.

Not content with managing a major project through to successful completion, Gerry went on in 1983 to take responsibility for the whole of the Company's R&T activities, when he was appointed HQ Director of Research. In 1989 Gerry was awarded the Order of the British Empire in the New Year's Honours List.

3. The Division Managers

Introduction

One of John van der Post's earliest actions was to appoint Group Leaders in each of the key technologies essential to realise his plans. These were the forerunners of the later divisional structure and covered: Materials, Design, Structural Engineering, Control & Instrumentation and Thermodynamics. Changes of name were made from time to time over the years, but these skills have featured one way or another in the divisional make-up of ERS through to the present day. Materials is perhaps the only one to span the years with its name unchanged, whilst others have taken various forms in line with the particular application emphasis at the time. For example, Structural Engineering split into Transmission Engineering and High Pressure Engineering and eventually became Engineering Science, incorporating remaining aspects of Thermodynamics. Fracture mechanics moved between Materials and Engineering Science more than once over the years. Control & Instrumentation was structured to give rise to a separate Control or Systems Division and an Electronics & Instrumentation Division, which in turn spawned Planning & Communications in 1984. Design was all pervading throughout this time, although as a specific descriptive term it can only be found in the area of gas distribution technology. The extent and frequency of these changes adds complexity to the attempt to tie together the Division Manager stories. It was not until the introduction of the full scale matrix structure in 1992 that the basic disciplines essential to engineering research clarified to present a picture with many similarities to that established by John van der Post some twenty-seven years earlier.

As custodian of a basic skill or discipline, the Division Manager role represents the 'linchpin' of ERS. It involves organising and motivating staff, including training and education. It must establish close links with similar skills elsewhere in industry and academia. Above all, the Division Manager must always be 'on top of the job' and deliver the goods to the 'end-user' on time and to budget. A manager who excels in all these areas soon moves on and up - as experienced by several who have served the Industry through ERS. Several such cases have been recorded earlier in the Directorate section; others are recorded in the following 'Where are they now' section. In conveying the individual stories, the approach followed will be that of superimposing the personal stories on a tracing of the development and progress of the basic disciplines represented by each of the Divisions.

Structural Engineering

One of the first recruitment decisions made by John van der Post was to appoint Derek James to head up a Structural Engineering Group. Derek's previous experience was in aircraft engineering and, in particular, his work with Christopher Cockerill, the Hovercraft pioneer, gave him a broad basis of engineering knowledge that he was able to put to good and immediate use in the rapidly changing engineering requirements of the Gas Industry at that time.

Derek joined British Gas in September 1965 and initially much of his time was spent on naphtha reforming plant problems, specification writing and trouble shooting. However, in the early 1970s he was appointed Manager of a High Pressure Engineering Division and, in this role, made a substantial contribution to the development of various safe forms of high pressure storage of gas, which was a major area of new investment by the Industry at that time. In this connection his paper, co-authored with Arthur Smelt and entitled 'Testing and Evaluation of Pipeline Components and Control Equipment', which was presented to the Autumn 1973 Research Meeting of the IGE, was awarded the H E Jones London Medal.

Derek left ERS in 1975, but about 18 months before his departure he was given the task of considering how ERS might contribute to offshore technology. He approached the topic in an imaginative and perceptive manner, but was somewhat before his time and was unable to gain the necessary commitment from the Company to proceed. However, history ran its course and his early work provided a jumping-off point for what was to become a major part of the Station's future programme.

Derek's quiet and studious approach to engineering, combined with his strong theoretical competence, won him many admirers and friends, both within the Company and amongst its principal suppliers and contractors. Derek laid the foundations for structural engineering expertise at ERS upon which the undoubted success of the Station was built.

Derek was succeeded by Dennis Neale, yet another fugitive from the aircraft and power generation industries, who arrived at ERS in the first expansionary wave of the late 1960s. His recruitment arose from a chance meeting with Derek James, in 1968, at a Symposium on Fracture Mechanics.

Dennis graduated from Imperial College, London University, in 1953, with a BSc honours degree in aeronautical engineering and subsequently served a graduate apprenticeship with the Vickers Aircraft Co. He joined that company's engineering departments at Weybridge, initially as an aerodynamicist, but later moved into the stress office.

A move to Foster Wheeler/John Brown followed in 1965 and it was whilst working on the stressing problems encountered in steam raising and power generation plant that he encountered Derek James, at a time when John Brown were trying to persuade him to to relocate to Rochester in New York State! Derek was able to persuade him that the peace of Northumberland, not to mention the challenges and opportunities of ERS, were a better choice.

Dennis played a significant role right from the outset, on the structural behaviour of pressure vessels, pipes and other gas transmission related components, building up the Station's great strength in numerical and analytical methods in the domain of stress analysis and fracture mechanics. Little, if any part of the high pressure engineering programme escaped his attention. Indeed his advice and counsel were often sought on a wide range of topics, ranging across the whole of the programme underway at any time during the history of ERS. Dennis possessed outstanding technical abilities which won him universal respect from his colleagues and ensured that, in his own 'somewhat behind the scenes way' he had a beneficial influence on many areas of output from the Station.

Dennis was a reluctant manager. At the outset he was hesitant in taking up the post of Division Manager, High Pressure Engineering, when it was offered to him. He felt that he could use his time much more effectively on technical matters and rather over-estimated the demands and adverse influences of divisional administration. He also preferred a role as 'one of the boys' and while he could take tough decisions, he would rather they were not put before him in the first place.

When the Station began to move in earnest into the area of offshore technology, Dennis 'came into his own' once more. Here was an area that demanded his extensive engineering knowledge, flair and unfailing commonsense. One of the early successes was the rapid investigation and solution of a troublesome and costly problem encountered during exploratory drilling in the English Channel. This success was enthusiastically led by Dennis. It was the first positive step that put ERS onto the offshore engineering map and led to a rapidly growing programme of work in later years, with strong support from 'user functions'.

Dennis Neale came to the North East as a confirmed Southerner. He never tired of complaining, particularly about the weather, insisting that he would take any sensible opportunity to move back South. But he never did and indeed when he retired in 1993 he stayed put, having become very fond of the area. The complaining words are now something of an act that he is expected to perform! In retirement he is playing a leading role in a wide range of leisure activities, to the benefit of himself and many of his old friends and colleagues. Dennis always had a well developed sense of adventure and fun. In his younger days he built and raced motor cars, giving him unsurpassed knowledge of matters 'automobilia'. In his prime he took up the sport of hang-gliding (encouraging others at ERS to follow suit) until wiser counsel prevailed after minor mishaps! He now spends his time skiing, mountain biking and hill walking, with golf and bowls in the remaining spare moments. Dennis certainly left his mark on ERS - in more ways than one!

Following Dennis's retirement, the Division Manager post went to Jane Haswell, the first woman in the history of ERS to achieve this level of seniority.

Pipeline Engineering (Design)

Another of John van der Post's very early appointments was that of Keith Richards, who joined the team in September 1965 as Leader of a Design Group.

Alan Spearman joined ERS in February 1967, having previously seen military service in India, worked in aerospace engineering in Canada and the USA, as well as in industrial development work in both the USA and the UK. On arrival at ERS Alan was given the task of setting up and running a Technical Service Division.

1970 Medal Winners

John Newcombe (HE Jones London Medal), Keith Richards (SBGI Silver Medal), Alan Spearman (IGE Gold Medal).

Alan's practical background and extensive experience served him well and he influenced an impressive range of people and activities within the Station, covering both technical and administrative matters. He introduced a Project Sheet system for his Division which pointed the way to be followed by the rest of the Station. He set up a Metrology Section, which later became a vital part of the central workshop services and he played a key role in the establishment of the ERS Library and Information Service.

Alan's principal contribution, however, was in gas distribution technology. ERS came on the scene at the time when it was realised that dry reformer gas was having an adverse and serious effect on the hemp filled joints in the cast iron distribution system. It was clear that urgent remedial action was needed, but what could be done without exposing the Industry to excessive expenditure?

Initially, then, Alan worked in close co-operation with Keith Richards and David Howard on the development of the Staveley Joint Repair Kit. At a later stage he enhanced his role in this area, both in establishing extensive system modelling data and in master-minding the development of improved leakage control equipment. He was co-author, with Bill Pickering (of East Midlands Region) and Maurice Tanner (of LRS), of a paper 'Leakage Control in the Natural Gas Era', which examined the extent of the leakage problem facing the Industry in monetary terms and outlined the measures available for its control. The paper was presented to the 1977 Autumn Research Meeting of the IGE and was awarded the Institution Gold Medal.

The work continued for many years, encompassing encapsulation, 'bridge the gap' systems, improved rubber seals and both oil and glycol fogging. Most of these developments were licensed to UK manufacturers and found extensive use within the Gas Industry. Alan made a particularly strong contribution in the field of rubber seals, in which he was able to draw heavily on his experience in American aerospace. He was directly responsible for drafting and gaining the acceptance of specifications of rubber components for a wide range of applications. He was also involved in the first steps taken towards the large scale adoption of plastic pipes for low pressure distribution, drafting the initial specification. He insisted that the standard colour should be yellow rather than black, in order to aid identification in the underground environment.

Few areas of distribution technology escaped Alan's attention. He participated in the establishment of the Distribution Incident team under Les Hinsley and played a leading role in the distribution training courses for Area Board (Regional) engineers, which eventually became a mainstay of the School of Engineering when it opened on the ERS site in 1978. Through his responsibility for the central design and drawing office, Alan also made a significant contribution to the development of many items of 'hardware' in both distribution and transmission areas. These included Iris-stop, rapid hole diggers, autogrit blasters, corrosion assessment equipment, the drop weight fracture test equipment, ring tension test equipment and many other items which played an important role in the ongoing work of the Station.

Alan Spearman was also 'in at the beginning' of the study of transmission pipeline fracture, influencing the early metallurgical, welding and inspection work, including the establishment of the world renowned Inspector Approval scheme. He played an important part in a number of developments, including the design and construction of the large scale flow test facility at Low Thornley and later its bigger brother at Bishop Auckland, the assessment and later the design of flow control equipment that ultimately led to the development of the high pressure regulator and the gas control module, and the introduction of electronics into everyday gas-related activities.

Alan Spearman was something of a workaholic, with a deep interest in technology and its application. He applied a great deal of energy and time in attempting to keep on top of all such things, so while he was usually the last to arrive in the morning, he was almost always the last to leave in the evening. Similarly, he was reluctant to surrender any areas of responsibility, even when more urgent matters were pressing. As a result, while he initiated a great many vital projects, he did tend to underestimate the importance of the guiding hands of others in bringing matters to an effective and full realisation. However, the achievements of which he can rightly be proud, were his IGE Gold Medal the very first Gold Medal to be received by anyone at ERS), his IGE Silver Medal, awarded in 1977 for his paper 'Improved District Pressure Control', and his election as Chairman of the North of England Section of the IGE for the 1985/86 session. It was in recognition of his wide scale of involvement in ERS technology that he was promoted to a specially created post of Chief Development Engineer, a post he held until his retirement in 1989.

Harry Tishler joined ERS in March 1970, to work under John Newcombe's guidance on aspects of flow measurement in the NTS. However, he quickly established himself as ERS' 'man of all seasons' and, over the years, has held numerous posts depending on the exigencies of the situation. Graduating from Liverpool University with an Honours Degree in mechanical engineering, he took up a post with the English Electric Company, and developed expertise in water hydraulics, before coming to ERS.

Harry's qualities of wide practical engineering knowledge, combined with mature management skills, were soon recognised and within a short space of time he was promoted first to Assistant Divisional Manager level and then, when Mike Rouse left, to take over the Systems Division. This led to his appointment as secretary to the Distribution Research Review Panel and its successor the Distribution Sub-Interface. In this role he willingly and quickly learned to assist David Needham in pressing for the acceptance of the ERS Distribution R&D plans, an activity which almost invariably met with success.

In 1976 he was appointed Manager of the Distribution Division and, following a reorganisation in 1979 he became Manager of a newly created Strategic Studies Division. In this capacity he was responsible for cost/benefit analyses of the Station's projects, as well as for the provision of a mathematical and statistical service.

In-between times, while Les Mercer was away on secondment, Harry spent several months in 1978 serving as acting Assistant Director, initially with responsibility for Administration and then for Transmission activities.

Several further moves took place in the 1980s, firstly as Manager of the Instrument and Operations Division in 1984, then as Manager of the Mechanical Engineering Division in 1989 and, finally, in 1991 to be Business Area Manager for Strategic Studies. He retired in 1993.

Apart from his very active interest in the IGE and other engineering institutional matters, Harry, who is married with three daughters, describes himself with typical humour as avoiding being completely henpecked by escaping to play golf (badly) and tennis (less badly) at every opportunity.

Of all the characters to emerge from ERS, none is more larger than life than Les Hinsley. The youngest child of the Emeritus Professor of Mining at Nottingham University, Les was the 'failure of the family' as all his siblings graduated from Oxbridge and Les 'only' made it to Battersea College of Technology, where he took an internal London degree in mechanical engineering.

Voluntary work in Africa preceded his employment with Hawker Siddeley where he developed an interest in fluid dynamics. He arrived at ERS in March 1970 and his early work was concerned with the thermodynamics problems associated with safety and gas systems. The section of the IGE Code of Practice TD1 relating to gas dispersion in the atmosphere, is a direct result of Les' experience in the aircraft industry.

In 1975 Les was appointed Assistant Divisional Manager in the Distribution Division, reporting to Harry Tishler. In this capacity he led the drive to bring sense and order to the products offered as solutions to the leakage of gas mains. Four years later, he succeeded Harry as Divisional Manager and was a major force in the establishment and operation of the Distribution Incident team.

Following Ernie Shannon's appointment as Station Director, Les became a Project Manager, but this position did not suit him at all well and, following a further reorganisation, he returned to work in the main Engineering Division. At the end of 1993, Les took his colleagues by surprise with an almost instantaneous decision to retire.

Les is known throughout British Gas, where opinion on his contribution has been sharply polarised. There are those who can forgive him his, at times, outrageous appearance and outlandish language, in the light of his undoubted engineering skills and the stream of ideas which he generates. There are others for whom his public utterances put him beyond the pale.

In 1978 Les was brought to some semblance of order by his courtship of the equally redoubtable Janis, the ERS Librarian. On the occasion of his marriage he asked his boss (Dave Needham) if he would be his Best Man, and Dave maintains he attended the Registry Office without prior knowledge of the identity of the bride!

Janis has had some impact on the man, put even she could not consign some of his prehistoric pullovers to their appropriate final resting place.

Brian Flood joined ERS in 1970, after spending six years with a neighbouring company, Merz & McLellan. Previously he had taken a degree in Mechanical Engineering at the University of London and had been a graduate apprenticeship with Rolls Royce.

Initially he tackled a range of problems, including aspects of the original development of on-line inspection devices and various distribution projects. His track record over this period proved that he was a shrewd operator, with the ability 'to make things happen' even if he ruffled a 'few feathers' in the process. The Director recognised these qualities when he gave Brian the responsibility of negotiating the rental of the Spadeadam site and its subsequent development for fracture propagation work. He was appointed Manager of a new Pipeline Engineering Division in 1978, with responsibility for most of ERS' large scale experimental work.

With the development of ERS' interest in offshore engineering, Brian was the driving force in the refurbishment of the Blyth Dry Docks into what became known as the Underwater Engineering Research Centre. He eventually became responsible for all the work undertaken at Outstations, including Low Thornley and Bishop Auckland, when the Experimental Engineering Division was formed following Ernie Shannon's reorganisation.

Brian's political views, and his high profile as a leading member of North Tyneside Council, did not always endear him to either his peers or members of senior management. The latter would have preferred him to concentrate on his career within the Gas Industry, rather than sharing it with an equally demanding role externally. It says much for Brian's energy that he was able to carry on both jobs, but perhaps more for the tremendous support which he receives from his own staff.

The Materials Division

The post of manager of the Materials Division has acted as the launching pad to a much more senior appointment for a surprisingly large number of its incumbents. The first three managers, in succession, were Les Mercer, Gerry Clerehugh and Tom Harrison, whose career developments are described elsewhere. Suffice it to say here that all three achieved appointments at least at Station Director level.

Materials Division 1982

Presentation to Dr R Wilkins on his departure to OLIC in 1984.

In 1977, after Tom Harrison's appointment as Assistant Director, Roy Wilkins was promoted to follow his guide and mentor into the Division Manager post. Roy joined the ERS Corrosion Group in 1967, straight from completing his PhD at Liverpool University. He, Tom and Arthur Brown worked together for many years as a close-knit team, tackling the many corrosion problems thrown up by the construction of the National Transmission System. Under Tom's watchful eye, Roy was encouraged to develop his managerial skills and when, in 1971, Tom was promoted to Division Manager, Roy took over as Group Leader of the Corrosion Group. His appointment as Division Manager was, therefore, the second occasion on which he succeeded Tom.

Roy left ERS in 1984 to join OLI at Cramlington in the capacity of Assistant Director with a brief to market the pipeline inspection service world-wide. After seven years at OLI, Roy took up an appointment with British Gas HQ as Regional General Manager responsible for seeking Company investment opportunities in power generation in North Africa, Eastern Europe and Asia.

Roy Wilkins was followed in 1984 by Phil Kirkwood, whose career development is again described elsewhere in this Section. The current Division Manager is David Batte, who joined ERS from the Research Department of C A Parsons in April 1985.

David obtained a degree in Natural Sciences at Cambridge and then went on to take a PhD in metallurgy. From University he went to C A Parsons, where he specialised in the deformation at high temperatures of steels used in steam turbines. In 1984 he received the Charles Parsons memorial award for his work in this area.

His initial appointment at ERS was as Assistant Division Manager, in which capacity he turned his attention to structural and pipeline steels. In 1991, with the coming of matrix management, he was promoted to take responsibility for the Materials Engineering Division, first only at ERS, but in 1992 also at the other Research Stations. Thus, all materials research within British Gas is now unified under his direction.

Out of work, David is a committed and active Church member, was a Church Warden for six years and is an elected member of the Newcastle Diocesan Synod. Commitment to Christianity evidently runs in his family, as his wife is an ordained minister.

Control and Instrumentation

John Newcombe was amongst the first batch of graduates to join ERS shortly after it moved to the North East in 1966. Like a number of other staff at that time, he was recruited from the International Research & Development Group, Newcastle upon Tyne, to become Group Leader of Applied Electronics, a post which eventually led to him being appointed Divisional Manager, Control & Instrumentation.

John was one of the first two ERS staff to win an award from the IGE (the other being Alan Spearman). In John's case it was the H E Jones London Medal, which he received with A.... Griffiths for a paper entitled 'Large Volume Gas Measurement' presented to the 1970 Autumn Research Meeting of the Institute.

John left ERS in 1974 for the Automated Systems Division of Vickers Ltd., but he returned to British Gas in 1979, joining Watson House as Engineering Development Manager. In 1993 he left British Gas once more to become Assistant Director of the Oil and Gas Measurement Branch at the Department of Trade and Industry.

John was followed as Manager of the Control & Instrumentation Division by Mike Sporton, who had arrived at ERS in October 1971 to work as a specialist Consultant under John Newcombe. Before coming to ERS, Mike read Natural Sciences at Cambridge and then moved to the University of Aberdeen where he obtained a PhD in Electronics.

After Mike's appointment as Manager, the Division went through a number of structural changes, but maintained at all times responsibility or a wide range of demanding technical topics. This was the centre of work on electronics, instrumentation and communications - all rapidly developing areas at the time. Mike was in his true element in this role - he was a man of ideas who just loved a technical challenge. He possessed a rare ability to pin-point the key issues, to think at the fundamental level, to plan the work to produce practical and usable results and, above all, to put the technology over to others in a clear, convincing and entertaining manner. He pioneered a number of innovations in this latter area, for example making one of the first multiple slide projector presentations to an IGE meeting. During his 14 years at ERS, Mike regularly demonstrated his 'showman' skills, usually combining the latest technological aids in combination with his unmatched personal abilities when 'on his hind legs'. He was regularly 'on call' to make presentations during visits of the Industry's senior technical committees and, in particular, to the Research Committee which, at the time, met under the chairmanship of Sir Denis Rooke.

As indicated, Mike Sporton was also responsible for a creditable number of technical innovations that went out from ERS to serve the operational needs of the Industry. Especially noteworthy were the various contributions in the area of gas detection and measurement. These included the range of GASCO instruments, contributions to vehicle mounted flame ionisation measurement (FIM) and sonic-based systems for gas detection. Together with Ian Whiteley, he also pioneered the whole concept of digital communications technology in the Industry. He established the basis of optical-based instrumentation, which grew in stature in later years after Mike left for other pastures.

Mike's skills and enthusiasm for technology extended beyond his place of work. He was computer literate from an early date and purchased a machine for his own (and his son's) use long before lessor mortals considered such things. Mike was also the leading light in setting up the male keep-fit group at ERS in the early 80s. In the late 70s, he led a small but dedicated team which entered a business competition run by the Scotsman newspaper. The fictional company run by the team was termed Randers Ltd. (R&D-ERS) and had Mike as the Managing Director. Whilst the team achieved success in the initial 'heats', the competition proved too powerful in the semi-final! This did not deter Mike. He later discovered the BBC Great Egg Race TV programme and, with typical enthusiasm and drive, led an ERS team to a good measure of success against stiff and semi-professional opposition. On top of all this, Mike found the time to become a visiting Professor in the Department of Electrical and Electronic Engineering at the University of Newcastle upon Tyne.

Mike's first love outside work was, and remains, music. Whilst in the Newcastle area he sang in several local choirs and through this medium met his second wife. Following his departure from ERS and their move to the Midlands in 1988 when Mike joined Lucas, they soon picked up new, but similar threads, in the Birmingham area.

Mike was universally liked and respected by his work colleagues. His great determination, powerful intellect, organised approach to work and formidable presentation skills, have all left their mark on those fortunate to work with, or alongside, him at ERS. Above all, he is simply a very nice person and at all times a gentleman.

As mentioned earlier, Gordon Pickard returned to ERS when the OLI Electronics Division was amalgamated with that at ERS, and became the overall Manager of the combined Electronics Division.

He had joined ERS originally in 1975 with the overall responsibility for the electronics associated with OLI equipment. He was eventually appointed Manager of the Electronics Division when the OLIC was established at Cramlington in 1979.

Gordon was born in the North East and educated at Barnard Castle School and Leeds University. He is a relatively private person, whose major characteristic is his tenacity to 'stick' to his own point of view. This proved to be a considerable advantage when it came to the difficult task of amalgamating two technical electronic units into one new Electronics Division.

Strategic Studies (including Maths and Computing)

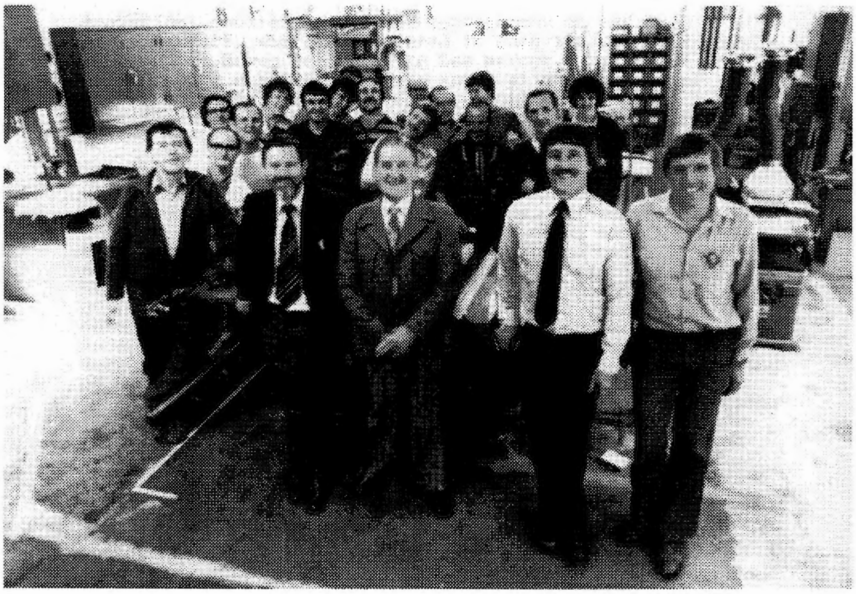
Analytical studies were first represented at ERS by David Randall, who was appointed in June 1967 to head up a Mathematics Group reporting to Les Mercer. David was a gifted young statistician, who inter alia made a vital contribution to the transmission pipeline purchase specification, before leaving early in 1970 to take up a senior post in the brewing industry.

Mike Rouse was one of many capable young mechanical engineer who joined ERS during the Benton Park Road days, before the Killingworth buildings became available. He was recruited in January 1967 to undertake design work in the distribution area, under Keith Richards. The plan was to build on Mike's experience with his previous employer, Massey Ferguson in Coventry, where he worked on the design of mechanical system associated with agricultural equipment. However, the pace of change was rapid in those days and Mike found himself working in an entirely different field soon after he arrived in the North East. He became involved in the assessment and testing of high pressure pipelines under David Randall in the Research Division. His role was to determine the appropriate statistical approach to build into pipe purchase specifications in order to avoid the risk of unacceptable forms of brittle fracture in service.

Uncertainties existed about the likely mode of failure during the pre-service ultra-high pressure water test and Mike became involved in the 'infamous' full-scale test on the Totley-Mirfield pipeline, high up on the moors near Sheffield. The test had to be carried out at a temperature below ambient and he recollects attempting to purchase several tonnes of ice, for immediate delivery, late one evening using a local call box and Yellow Pages! Water was everywhere that night - the rain broke all records - even for that notoriously wet area!

Mike stayed with this area of technology and, following an internal reorganisation, concentrated on strategic aspects of gas distribution under David Needham. His team included Bob Lacey and Edward Glennie, and the big achievement of this period was the direct measurement of distribution system leakage - a much more difficult task than is generally imagined! Conversion of the whole country to natural gas presented a unique opportunity and Mike was quick to grasp i and turn it into a valuable research and investment planning tool to the great benefit of the Industry. Mike had become Manager of the Distribution Division when, in September 1974 he departed to take up a senior post in the research arm of the water industry. By this action he started a trend - ERS as a 'training ground' played an important role in the development of engineering research in that industry.

Mike Rouse combined great competence as an engineer with a cheerful outward going personality. He was an accomplished tennis player and he left his mark in this respect, both at his local club and in the North East as a whole.



Site Services 1980 – On the occasion of Mark Bloor's retirement.

Laboratory Services Division

Jim McCourt was responsible for Lab. & Site Services Division from the time he was recruited by Brian Thompson, at the beginning of 1967, until his untimely death in 1990. Born and educated in Scotland, he arrived at the Station via an engineering apprenticeship at C A Parsons, a short spell as a marine engineer, and research experience with the Nuclear Power Group.

Jim's first task on joining ERS was to get the new Station ~up and running', an exciting but formidable challenge that he met with the drive, energy and professionalism that were his trademark. He remained at the forefront of the continued development as the site doubled in size over the next 20 years, to include an extension to the main building, construction of the 'test cells' and the School of Engineering, and the amalgamation of the 'ex-Government Skill Centre' into ERS.

The division rapidly became the largest in terms of manpower at ERS, since it contained a 'pool' of engineering technicians who, when not working in the workshop, were seconded to help with project work in a laboratory or in the field. This pool concept, introduced by Brian Thompson and developed by Jim, had the double advantage of providing excellent training experience for technicians, as well as enabling skilled labour to be provided on a flexible basis. Jim recruited Terry Poppelwell in 1967 as workshop manager a post he held until his retirement in 1993. Terry was ably backed-up by a group of Chief Technicians who were responsible for management on the 'shop floor', including Bill Darke, Arthur Monaghan, Eric Johnson, Jim Ideson, and Jack Coatesworth.

Jim's private life revolved around his family and, although basically a shy, reserved man, he could be good and entertaining company. A Scotsman of the traditional school, he meticulously celebrated Burn's Night; a striking, bearded figure resplendent in kilt, 'wee dram' in hand, as the time honoured Haggis was piped in.

Although his management style could be fairly direct and uncompromising at times, he was a popular figure throughout the Station - his early death was a great shock. Those members of staff who worked closely with him will always remember him with affection.

Jim was succeeded by George Burdon, who had been his right hand man for a number of years. He had joined ERS in 1979 as Site Services Engineer. Following an apprenticeship on the Tyne, he qualified as a marine engineer and spent several years at sea, during which time he found himself a shipmate of Jim McCourt's, a fact which George only brought up with Jim after he had been installed in the job at ERS.

George's previous experience with numerous engineering companies, some at a senior management level, had ill-prepared him for the culture shock he experienced on joining ERS. Despite any initial doubts he had concerning the rather egalitarian regime at ERS, he stayed to make a major contribution to the Station's development during the 80s and 90s and, as the Station's Safety Engineer, was able to generate an increasing professional attitude to cope with the ever increasing legislation being introduced during this period.

Following the purchase of the Government Skill Centre, adjacent to ERS, it was decided to carry out the necessary modifications using in-house staff, without using architectural consultants as in the past. George took on the role of project leader and, working with limited finance, met tight deadlines to budget.

George had considerable writing and musical talents, which came to the fore at Christmas time. Over a number of years he was persuaded to mastermind the script for the Christmas pantomime and participate in its production. Perhaps it says much for his character that his relationship with Jim McCourt and Tom Harrison survived the various attempts at character assassination that occurred on these festive occasions.

Management Services

Administrative Services Management team 1976.

During the first 12 months of ERS' existence, Brian Thompson was 'Mr Administration'. He was joined in the middle of 1967 by Mervyn Piper, who became Scientific Secretary and eventually the head of the department. John van der Post recognised that if the Station was to become a success then it was essential to recruit people of quality within all departments. Thus, when Mervyn, then working as a physicist with Plessey, applied to join ERS but indicated that he was looking for a career change, he was welcomed with open arms.

As a new Station, starting virtually from scratch, there was much to be done to establish all the basic procedures, recruit staff and arrange the transfer into the new laboratories, in 1968.

Mervyn's character was something of a contrast to that of Brian's, who was more open and straightforward. However, they worked very well together, starting off each day with an early morning brain-storming session. Afterwards Mervyn did his best to implement the decisions taken, attempting to prevent Brian from interfering and getting involved in the detail.

Mervyn was always immaculately turned out - smooth and articulate (with a slight Welsh lilt) - this explained the affectionate private name which his staff had for him, 'Merve the Swerve', after the famous Welsh rugby forward. Like Brian, he was quite prepared to speak his mind and this increasingly led to conflict with the Director and a subsequent deterioration in their hitherto good relationship. By 1975 he was ready to move on and eventually joined the HQ Secretariat.

Following Mervyn's departure, Martin Crompton joined ERS briefly (2 years), recruited externally from a Management Consultancy. The move was not a successful one, as Martin was never able to establish accord with the Director and many senior members of management. He eventually emigrated to Australia, leaving the door open for Nick Southern to take up the senior post.

Nick had started his professional career with ICI, Billingham, as a graduate apprentice after graduating with a Mechanical Engineering degree from King's College, London. Following a spell with Consumers' Gas, Canada, he returned to England in 1970 and joined ERS, working with Mike Rouse on strategic studies. In 1972 he joined the Planning Section to assist Mervyn with the introduction of the, then new, McKinsey Planning Cycle.

Although Nick inherited a well organised unit, morale was low. There was a need to reorganise certain groups and prepare for a programme of modernisation, in order to benefit from a programme of capital expenditure that was taking place to introduce word processing, a modern telephone exchange and computerised graphic design equipment.

A major effort was also undertaken to provide software (CEPA) enabling project costing information to be available to project staff. Experience with this programme enabled a more integrated management information system (MISERS) to be introduced, which was eventually used as the basis for the new divisional RADMIS system, introduced in the late 80s.

From the mid 80s, Nick pioneered the development of project appraisal methodology, which came into its own after the Company reorganisation in 1990 and R&D found itself having to carry out detailed justification of projects in order to acquire the appropriate budget.

Following Dr Shannon's appointment and the organisational changes that followed, Management Services was reorganised again to include the computing services group. When this had been completed, a mature and well run organisation was achieved, which proved valuable in helping to keep ERS running smoothly at a time when R&T was undergoing considerable upheaval with the closure of the three Southern research stations and the opening of the GRC.

4. Where Are They Now?

This section provides a brief account of the progress of some of the people who worked at ERS after they left to go to other parts of British Gas. In the early days of ERS the development of the national transmission system resulted in the expansion of the, then, Production & Supply Division and offered numerous opportunities to ERS staff. The first of these came with the transfer of quality control to British Gas HQ.

As noted in Part 1, Ron Gibbon (1966/68) was persuaded to go to London to set up the new Quality Control unit and his subsequent career has probably been the most distinguished of any ex-ERS member so far. After a number of appointments at progressively increasing levels of seniority, he became Director, National Transmission Operations within Gas Business, the position from which he retired in 1992. In 1988 he was elected to the Fellowship of Engineering and in the 1991 Birthday Honours list he was awarded an OBE in recognition of his very significant contribution to engineering development in British Gas.

After his departure to London, Ron was soon joined by a number of other ex-ERS colleagues including John Cameron (1967/70), Tony Doherty (1967/71) and Tony Birkbeck (1967/71). Following the first of Ron's promotions, John Cameron became Manager of the Quality Control department, which has eventually become the Quality Systems and Audits department. John retired in 1993 and at the time of writing Tony Doherty holds the post of Acting Departmental Manager.

A further ERS recruit who has risen to a prominent position is Dr David Ingham (1974/6). On leaving ERS he took up a post within P&S. Over the next ten years he gained experience in a number of fields including machinery, construction, design and plant operation before moving again to a Regional appointment. Subsequent progressions have led him to succeed Ron Gibbon in 1992 as HQ Director, National Transmission Operations.

The Pipelines Department also attracted a number of specialist staff from ERS including Dick West (1970/6), Brian Cassie (1971/6), Tom Avery (1967/74) and Dave Johnson (1969/76). Dick West was recruited to establish an Engineering Services Group, a position which he held for several years before moving outside the Industry. Brian Cassie joined Pipelines as a Welding Engineer and in 1990 was appointed Technical Resources Manager within the Project Resources Department. He retired in 1993. Tom Avery also joined the welding side of the Pipelines Department and was often seen back at ERS assisting Ron Chrisp with the Inspector Approval Scheme. Dave Johnson, a Coatings specialist, joined the Cathodic Protection Section of Pipelines.

Three of the original LRS ten (Brian Huggett, Derek James and Keith Richards) moved back to London. Brian Huggett joined the P&S Division in 1970 and has since worked in the Machinery Department, of which he became manager, and on the Rough and Morecambe Bay Projects. He is now Construction Manager within Global Gas. Derek James joined the Engineering Planning Department in 1975 and held a number of posts in that and the Construction Department, including four years as Engineering Manager on the Morecambe Bay Project. In 1989 he was appointed Design Standards Engineer in the Construction Department, and that was the post from which he retired in 1993. Keith Richards was initially seconded to R&D HQ in 1977 to explore the possibilities of securing external funding for R&D. The project was so successful that a new post was eventually created for Keith as Commercial Development Manager. In 1990 the technology licensing aspects of the work were transferred to Global Gas as a separate unit under Keith. Keith retired in 1993.

Chris Austin (1968/74) followed Brian Huggett to London initially acting as Assistant Manager of the Machinery Department responsible to Brian, and then taking over as Manager when Brian moved on. In 1991 Chris took up a new appointment in the Construction Department.

Over the years ERS staff have, of course, also moved to Regions and examples of a few of those who took up such appointments now follows. Again the process started fairly early on after ERS was established. One of the first to move was Mike Heath, who was another of the original LRS contingent. Mike never really settled in the North East and was more than glad to return to the Home Counties when he obtained a post with Southern Region in 1968. Mike retired in 1990???

Another early leaver was Bryan Horsefield (1967/9) who had joined ERS as a welding specialist. Bryan also went to Southern Region where he took up an appointment as Welding Engineer. He left British Gas in the early 1970s.

Further examples of Regional appointments were Stuart Carrick (1967/74), Keith Nixon (1974/85), Garth Hedley (1974/8) and Peter Dodds (1973/82). Stuart moved to North Eastern Region as Assistant Distribution Engineer and has stayed with that Region holding a variety of Regional HQ positions within the Engineering Department. Keith Nixon joined the South Eastern Regional Central Laboratories. Some time later environmental issues were added to his remit as a consequence of which he eventually took up a position as Environmental Manager with British Gas HQ. Garth Hedley and Peter Dodds both joined North Western Region, Garth as Transmission Engineer and Peter as a member of that Region's Quality Assurance Department.

On the non-technical side, reference must be made to Mervyn Piper (1967/75) who left ERS to become Assistant Secretary in the British Gas HQ Secretariat and some time later became Regional Secretary of the North Thames Region.

Following the Company reorganisation in 1991 he transferred to East Midlands Region as Director of Services and retired in 1993.

John van der Post and all the subsequent Directors of ERS were always keen to encourage Regions to give their young engineers several years' experience at ERS as part of their professional development. While few took up the opportunity, four exceptions were Malcolm Hornsey (1967/9), Alan Fisher (1972/7), Arthur Stout (1972/5) and Mike Weale (1980/9) Malcolm came to ERS from South Western Region and eventually returned to that Region as Grid Engineer. His career has since taken him to North Eastern Region and then to the West Midlands Region where he is Regional Director of Engineering.

Arthur Stout came from North Western Region and left ERS to go to North Eastern Region. He eventually joined Global Gas in 1991, where he became Technical Services Manager responsible for a wide range of activities in transmission and distribution. As such, he is a frequent visitor to ERS with prospective customers from all over the world. Alan Fisher was a Distribution Engineer with the Wales Region before joining ERS. Consequently he was able to make a significant input into a number of Distribution related projects while at ERS. In due course he left to take up a Distribution engineering post in South West Region. Mike Weale joined ERS from the East Midlands C&I Department where he had gained considerable experience in telecommunications. Having played a significant part in the development of mobile radio networks within Ian Whiteley's group at ERS, he moved to take up a position within the C&I Department of the Scottish Region.

By the early 1980s, the opportunity for further advancement at ERS was more limited than hitherto and this led to the departure of some very talented engineers to other parts of the Industry. Three Assistant Division Managers sought their progression elsewhere in the Industry; Keith Smith (1966-80), Ken Bray (1976-81) and Malcolm Howe (1972-82).

Keith Smith joined ERS in 1966 and worked mainly on stress analysis in Structural Engineering. He joined the team at HQ which was involved in the project relating to the development of a North Sea gas gathering pipeline. At the end of that study, he remained with the Resources & External Affairs Division, eventually amalgamated into Global Gas, until he retired to the Lake District in 1993.

Malcolm Howe worked in the Distribution Division at ERS until he joined the Headquarters Distribution Engineering Department where he stayed for seven years, finally as the Departmental Manager, before being appointed Technology Regulations Manager in 1991 in the Company's Regulatory Operations Department.

Ken Bray joined ERS as an Assistant Division Manager, and did much to establish up-to-date computing facilities at ERS during the late '70s. He transferred to South Western Region, initially in their Management Services Department, and later being appointed Director of Servicing. He joined E&P Division at HQ in London, eventually being appointed their Controller of Management Services, a post he holds today at the new Reading Headquarters.

John Wilkinson (1970-82), who contributed much to the development of the Gas Control Module at ERS, joined the International Consultancy Service in 1982, which was eventually amalgamated into Global Gas after the Company's reorganisation. He was appointed, and remains, Resources Manager for Technology Development in 1992.

Paul Banks (1990-91), who was the first member to transfer from LRS to ERS in 1990 as a Principal Engineer, worked briefly in the Maths & Computing Department before leaving 1991 to join the HQ Telecommunications Group.

Ann Cairns (1979-85), a talented mathematician, joined Transmission Engineering Department at HQ (??) where she worked for several years before leaving the Industry.

Not only did ERS staff go to British Gas HQ and the Regions, but on occasion they also went to other Research Stations. Examples of such moves are John Newcombe (1966/74), George Duthie (1976/81) and Dr Mary Harris (1981/7). John Newcombe was a very early recruit, joining ERS in September 1966 as head of the Control and Instrumentation Group. Although he left ERS for the Automated Systems Division of Vickers Ltd., he returned to British Gas in 1979 joining Watson House as Engineering Development Manager. In 1993 he left British Gas once more to become Assistant Director of the Oil and Gas Measurement Branch at the Department of Trade and Industry.

George went directly to MRS, while Mary was appointed Leader of the Watson House Materials Group. She had progressed to Division Manager before securing a senior appointment in the Corporate Strategy Department where she continues to interact with R&T. Truly a poacher turned gamekeeper!

Finally mention should be made of the Region to recruit the greatest number of ERS staff, which not unnaturally was Northern. Some of these staff gained positions within District or Regional support engineering management, as would be expected, but others progressed along somewhat less obvious routes.

George Milne (1967/73) was the first to transfer, joining Northern Region's Production Department, moving on to transmission activities at Regional HQ when gas manufacturing was discontinued in 1977. A further three staff, David McGeagh (1967/75), Chris Gorman (1966/82) and Brian Morris (1979/80) have also taken up posts at Regional HQ. Although David's original training was in metallurgy, he made a successful transition into the mainstream of engineering, as evidenced by several promotions and his becoming Chairman of the Northern Section of the IGE in 1990/91. Chris is one of that very select band of engineers who gained Chartered status through the examination route. Soon after joining Northern Region he became an early member of the Safety and Standards Department. Although Brian joined the Plant Design Section, since 1988 he has held the position of Assistant Grid Controller.

To date three staff, Tony Beeton (1970/9), Alan Rivers (1967/78) and David Thompson (1968/78) have left ERS to take up posts within the Region's District management. Two others, Tony Burton (1968/77) and Joe Miller (1977/8) joined the technical training side of the Region's Training Department.

In addition there were a number of less orthodox progressions. Dick Ayling (1978/82) joined the Northern Region's Corporate Planning Department to be responsible for the production and analysis of management information. He left British Gas in September 1993 to take a MSc in Computing.

Probably the most unusual moves were made by Bob Weiner (1966/74) and Susan Jones (1977/88), both of whom moved to the Personnel Department. Bob joined ERS as Group Leader of the Mechanical Properties Group but by the early 1970s had decided that his preferred career lay in personnel management rather than in technology. Consequently Brian Thompson, in one of his typically far-sighted moves, arranged for Bob to be seconded to the Northern Region's Personnel Division and as so often happens the secondment turned into a permanent appointment. Bob eventually became one of the doyens of the Personnel Division and retired from his position as Assistant Personnel Services Manager in 1991.

Similarly Susan Jones, who was Administrative/Training Assistant in the British Gas School of Engineering, gained membership of the Institute of Personnel Management in 1988 (being awarded the John McGlen trophy for student achievement as the culmination of her course of studies). She then secured a 12 month secondment in the Northern Region's Personnel Division and again the secondment became a permanent appointment. Susan's connections with ERS have not, however, come to an end, as in 1982 she married Lee Jones (Group Leader - Structural Materials). Susan and Lee now pursue parallel careers as the parents of two young daughters.

In more recent times, a number of young graduates have left ERS after a few years research experience, to join operational departments with E&P. They include Gillian Johnson, Alan Bennett, Fred Chadwick, Ian Stewart, Matt Farrelly and John Shears.

SPORTING OCCASIONS

ERS Football Team 1982.

Sports Day 1985.

ERS Cricket Team.

May 1969 North Shields won the FA Amateur Cup.

Brian Joicey who scored the winning goal at Wembley (3rd from left) with ERS colleagues. He then decided on a professional football career playing for Coventry and other clubs.

Part 3 –

The Major Technological Successes and the Consequence and/or Benefits for the Industry

Introduction

Parts 1 and 2 of this history deal with the development of ERS and the people that made it happen. This third part is devoted to an account of some of the individual projects which are judged to have made a significant contribution to the application of efficient and safe engineering practice within British Gas. Inevitably the same proviso applies here as to Part 2, in that a considerable degree of selection has had to be exercised and, again, projects which others may feel should have been described have had to be omitted due to lack of space. Similarly, even though each article is attributed to one or two authors, the work described is, in fact, the outcome of input from a whole team and, again, lack of space may preclude every contribution being mentioned.

In following John van der Post's philosophy of ensuring that research and development was constantly in close contact with the experiences and problems of the Industry's operational engineers, projects at ERS tended to mirror developments in the field. So initially much effort was devoted to the problems experienced with naphtha steam reforming plant, and the first article by Les Mercer describes this work. With the discovery of North Sea gas, attention switched to high pressure gas transmission and 8 number of papers describe the work undertaken to make this as safe an operation as possible.

Once a substantial part of the NTS had been constructed, the emphasis of the work shifted again to focus on the safety and cost effectiveness of low pressure gas distribution. New methods of measuring and controlling leakage were developed, new materials and components were pioneered and the labour intensive nature of the pipelaying operation was considerably reduced. The third group of papers describes some of this work.

In the 1980s, when British Gas became interested in offshore gas exploration and production, ERS rapidly developed expertise in this area of engineering technology and the final paper describes work undertaken in support of this new development.

INVESTIGATIONS OF STEAM-NAPHTHA CONTINUOUS REFORMING PLANT

by Les Mercer

1. Introduction

The Research Engineer's Department at LRS came into being in 1964, at a time of great change in the Gas Industry. Gas production, using the new steam-naphtha continuous reforming process, was starting to be introduced and the associated high pressure, high temperature, technology was a new and somewhat daunting terrain for many of the Industry's engineers used to dealing with the traditional methods of manufacturing and distributing town gas. This is an account of the involvement of John van der Post's team with the new means of gas manufacture, ranging from these early days at Fulham to the establishment of ERS at Killingworth and its brief further involvement with the topic.

A milestone in this story came with the Conference, chaired by Dr Albert Haffner (of the Southern Area Board), at Brighton in May 1965. Reference has already been made in Part I to this Conference, at which the opinion of most of the Area Board plant engineers present was that metallurgical failures were responsible for the majority of the problems being experienced. However, the data presented indicated that, whilst materials selection and fabrication could be improved, many of the problems being experienced were more widely based. Aspects of plant control and staff training to improve knowledge of the new technology were equally, if not more, important. These factors were all to feature in the developing programme of the new team during the following months and years. The importance of this occasion, and the way it just had to influence the emerging 'research' programme, can be judged from the fact that, by the summer of 1966, some 30% of the total output capacity of the Gas Industry was vested in continuous steam-naphtha reformers!

2. The British Welding Research Association Joint Programme

The embryo ERS team initially placed much emphasis on forging close working links with the various plant designers, manufacturers and component suppliers. Primary amongst these were the ICI engineers and technologists based at the huge agricultural products site on Teesside. Operational problems encountered were clearly of concern to both organisations and direct and deep collaboration was of inestimable value. ICI, in the person of Dr Costi Edelaneau, had already taken the initiative in establishing a mechanism for broad ranging collaboration before van der Post's team came into being. An open symposium on reforming technology was run in 1964 and this led to the formation of a Group sponsored programme of work which was undertaken at the British Welding Research Association (BWRA) laboratories at Abington, Cambridgeshire. The programme was overseen by Dr Bob Baker and the project was led by Derek Haddrill, who later became an early member of the ERS metallurgical team. The work continued over several years and made a most important contribution to the understanding of the underlying metallurgical behaviour of key plant components and to specifying effective methods for fabrication and repair. The sponsoring organisations included plant operators (ICI, Gas Council), plant designers (Humphreys & Glasgow, Power Gas Corporation, Whessoe, etc) and alloy tube manufacturers (APV, Lloyds Burton, etc). The Metallurgy Department at Leeds University, and Professor Jack Nutting in particular, were also deeply involved in the work.

It was the results of this joint programme which formed the basis of the paper to the IGE Autumn Research meeting in November 1966, mentioned in Part I of this History. The paper was essentially a basic lesson for gas engineers in the metallurgy of reformer components, covering the underlying fundamentals of structural behaviour, weldability and corrosion. As such, it provided a foundation for a growing dialogue between research and operational personnel. Many formal and informal meetings took place at this time. Symposia were organised on a regular basis at ERS and engineers from all parts of the Industry, ranging from senior management levels down to the most junior plant operator, were frequent visitors to the new research station.

3. The ERS Contributions

Whilst work at BWRA was proceeding, the Gas Council team was developing its own programme and continuing to recruit appropriate skills. Tom Harrison came from the electricity research laboratories at Leatherhead in Surrey, to establish broad ranging corrosion expertise. Dennis Clarke, previously at the Springfields (Preston) plant of the Atomic Energy Authority, came in to handle detailed metallographic studies into plant failures. Istvan Toth was recruited to initiate fundamental studies into the long term behaviour of advanced materials at high temperatures and, on the structural side, the team acquired Denise Durand, a young female engineer from France, who contributed much of fundamental significance during the following two or three years. The ERS team concentrated its efforts on three broad fronts, which will now be described.

As part of implementing John van der Post's philosophy of close interaction and a practical 'down to earth' attitude, the ERS team also offered a wide-ranging trouble shooting service, usually in response to real and urgent problems actually being encountered by the Industry. For example, dry natural gas from the Canvey terminal and increasingly, dry town gas from reforming plant, were causing severe wear and sticking of piston rings in reciprocating compressors. This gave rise to a major area of study, again in close collaboration with manufacturers, that resulted in design and key materials changes in these vital machines. At the other end of the scale, problems were encountered with severe stress corrosion cracking in certain pipelines conveying high pressure gas from reforming plants to consumers. This proved to be due to the presence of carbon monoxide, which was inhibiting the normal corrosive attack of carbon dioxide and thereby concentrating its effects at sensitive sites on the surface of the steel and so producing localised cracking. The basic problem was moisture - too much of it. Attack was occurring where moisture in the gas condensed out and accumulated - usually at low points in the pipeline some distance from the gas manufacturing plant. Notwithstanding the protestations of the plant engineers that wet gas was never sent out from the works, the solution was applied at that point. It was simply to ensure that the drying plant was performing to specification and not passing wet gas forward into the outlet pipeline.

There were many similar and parallel examples at this time. The solutions did not require research; they simply needed the proper application of what was already known. This is where the wide ranging skills and experience of the new ERS gas engineers came into use. Knowledge learned within, and collected from, other industries and applied in a direct and practical manner, was exactly what was required.

4. Reformer Header Tubes

As early as June 1965, a summary report was written for the Chief Engineer's Committee, outlining progress in the developing understanding of the metallurgical and welding behaviour of the highly alloyed cast materials. The header material, containing 18%

chromium, 37% nickel and 0.4% carbon, became severely embrittled in service as a result of a high temperature ageing process. This indicated a need ffor careful control of plant operations to prevent rapid changes in temperature, which could stress the brittle material to the point of fracture. This was the cause of several failures experienced during the first two or three years of reformer operations. As experience was gained such failures became much less frequent, reaching a point where they no longer were regarded as a significant threat to the Industry's well-being. However, in the meantime, a major effort was put into the selection of more robust materials for the outlet headers.

Experience in other industries suggested that wrought alloys of broadly similar alloy composition, but with much lower levels of carbon, would offer better service performance. These were much more costly, especially if every furnace was to be equipped with an outlet header precisely matching the size of the original cast component. Accordingly, ERS engineers undertook a wide-ranging study which led to a proposal for standardisation across the majority of existing and new plants, based on just four sizes of outlet header. At the same time, relevant operational data on the wrought alloys was collected from all possible sources. A trip to the USA was organised in March 1966, for this purpose. It involved Les Mercer, Derek James and Harold Hughes, the then Development Engineer of the South Eastern Gas Board. This provided much valuable data and strongly supported a move towards the use of wrought alloys.

Upon returning to the UK, the matter was pursued vigorously within the Industry, with materials and component suppliers and with furnace designers. A preliminary specification was put before the Chief Engineer's Committee in September 1966, to be followed by a final version in May 1967. The urgency of the situation was emphasised by a further distressing failure at the East Midlands Killingholme plant in October 1966, which resulted in the death of a member of the furnace operational team. However, as mentioned above, the ultimate and lowest cost effective solution came through improvements in plant control, probably spurred as much as anything by this very failure.

5. Stress Corrosion Cracking of Catalyst Tubes

A further problem, which exercised the minds of the ERS engineers, was that of stress corrosion cracking, usually at the relatively cool lower ends of catalyst tubes. Alkali potassium salts emanating from the catalyst, raised the pH of the condensate which then gave rise to stress corrosion attack of the susceptible austenitic material. One of the earliest reports on the topic was produced by Tom Harrison, in October 1966. While a number of approaches were tried to solve the problem, with varying degrees of success, surprisingly, the problem looked far worse than it proved in practice. Several furnaces operated over prolonged periods without failure, even though many of the tubes were weeping salts through a network of cracks. In one case, not a single tube failure occurred when a major boiler prime caused a total and massive failure of the outlet header.

The ultimate solution was also the simplest and indeed the least costly. It was simply to remove the lower end of each tube by cutting off the cool flanged section and replacing it with a redesigned outlet which swept the hot internal gases directly to the outlet header. This so called 'hot bottom', cast from material matched to that of the tube, was a complete and final solution. Why had the cool flanged section been utilised in the first place? It was to allow access to the inside of the tube in the event of catalyst jamming. Experience revealed this not to be as likely, and as serious a problem, as at first imagined and the loss of the feature was of little consequence. Another troublesome 'materials' problem was removed by a careful analysis of the situation and the adoption of an elegant design solution!

6. ERS Disengages

An update of the total scene occurred in September 1968 when an international symposium was organised in Brussels by the ICI team. By this time, the UK Gas Industry was operating some 200 furnace units, producing an output of around 85 million cubic metres of town gas/day. This was well in excess of the ICI experience, putting the Gas Industry in a world leading position having started from nothing only four years before! Ironically, it was also the end of the ERS involvement with gas production technology. The Station essentially pulled out of reformer-based activities by the end of 1968 in order to concentrate on natural gas-related matters. As it happened, a significant programme of work on manufactured gas continued for several years, but this was at LRS. Aspects of the ERS programme were transferred south, where they continued under the guidance of Fred Starr and went on to develop into new areas over a period of some years.

This briefly is the story of the major activity of ERS during its earliest days. The new recruits to an old and well established Industry were well and truly 'blooded' by the experience. It gave these engineers a unique opportunity to establish their credibility and to make the essential and close contacts with the 'sharp end' of the, then, rapidly changing Industry. They were exciting days that, to a degree, were to be repeated in the areas of high pressure transmission and, later, low pressure distribution technology. Those lucky enough to be involved may have felt unduly stressed at the time, but, in retrospect, they are able to look back to a remarkable era and to feel proud to have been a part of it and to have contributed in no small measure to its ultimate success. It was during this period that the fortunes of what had been a slowly dying industry positively turned for the better, in preparation for the truly golden days of natural gas.

LEAKAGE CONTROL

by Harry Tishler

1. Historical Perspective

The strangle-hold in which the National Coal Board held the Gas Council, because of its monopoly position as the supplier of coking coals used to manufacture 'Towns Gas', was broken by the development of the naphtha/steam reforming process. Building on earlier developments by Imperial Chemical Industries, research at the Gas Council's Midlands Research Station produced efficient reforming processes which were able to take advantage of a plentiful supply of cheap, light crude and refinery distillates, to yield a synthesis gas.

By 1963, areas receiving this new gas were beginning to show a disturbing pattern of mains' leakage. When the main was exposed at the site of the leak, it was an odds-on bet that a Staveley bolted joint would be revealed as the culprit. Many of the joints would have broken bolts, which would be replaced, all bolts re-tightened and the excavation filled in. Within a short time, the leak would often re-appear.

Similar problems had been encountered in the USA and Holland, when those countries introduced natural gas, the common link being that both the new synthesised and Natural gases lacked the aromatic content of town gas, as well as being dry. The effects of these changes in composition are explained in Section 1.2.

An engineering, rather than a plumbing, solution to the problem was required.

2. First Success

An investigation into the causes of the problems associated with leaking joints was begun by the Engineering group, recruited by John van der Post at the London Research Station, and was continued by them when they moved to Newcastle/ Killingworth. The investigation, led by Keith Richards, was concluded with the successful design and development of a repair kit which clamped a well engineered rubber gasket around the joint and could be used on several of the many types of joint which were then in use. The design of the kit was licensed to a commercial company, BTR Ltd. for them to manufacture and supply to the Area Boards.

The successful application of clamped gaskets was found to depend upon the skill and integrity of the person carrying out the repair and as an alternative, work at ERS focused on the problems posed by attempting to encapsulate the joint in a range of materials. These were sometimes injected into re-usable moulds and were cured after application to, or around, the joint. Many commercial formulations and systems of application were evaluated, in order to establish the parameters necessary for a successful outcome of a repair, free from leaks when operating under the conditions of a buried gas main.

From this work, led by Les Hinsley (he of the Awesome Sweaters!) there gradually evolved a set of Performance Specifications against which competing products could be judged. Caution could then be advised against the purchase, by the Regions, of unsatisfactory products. Similar evaluations of chemically based products, designed to fill, or bridge, the circumferential internal gaps between adjacent lengths of gas main were carried out at LRS, but external, gasket-type seals were in the work domain of ERS.

3. Leakage Control Policy

In 1965, British Petroleum was successful in finding a gas field in the Southern Basin of the North Sea, which was in in rock formation similar to that holding the earlier Dutch find at Groningen. The landing of natural gas from the West Sole field together with the prospect of vast supplies coming from the Leman Field led to the decision to convert all consumers appliances to burn the higher calorific 'new' gas, and meant that all Distribution Systems of the twelve Boards/ Regions would eventually carry very dry gas, which was also lacking in aromatics.

Literature searches were carried out, which revealed a potential for joint leakage to develop on a monumental scale. Estimates put the population of joints with rubber gaskets at around 15 million and of the older, jute-packed, run-lead, joints at around 24 million. The bone-dry, natural gas was known to promote the removal of water vapour from the jute and of aromatics from the rubber, both desorbing actions leading to leakage developing at the affected joint. Moreover, the increase in pressure required at the tips of burners of both new and converted appliances meant that the pressures in the Distribution mains would be doubled. This doubling, together with a doubling of the calorific value of the distributed gas, would lead to fourfold increase in the thermal energy lost, in any given period of time, to the environment. What, historically, had always been a toxicity problem for the Area Boards, because of the presence of carbon-monoxide in the unburnt gas would now become, essentially, an economic one.

Computer simulations of the cost of leakage control, which would arise under different scenarios of the effects of gaskets drying out, ie. the costs of 'leak Find & Fix' plus the loss of revenue vested in the 'lost' or leaked gas, were carried out at ERS by Mike Rouse and his team. It soon became obvious that the computer models required real data on the deterioration rates of the joints and on the lifetime variation of the effectiveness of repair techniques. Thus, ERS, on behalf of the Gas Councils Leakage Working Party, organised and supervised many 'field trials' in the Districts of the Area Boards, in order to generate the required data.

The outcome of a wide ranging and thorough investigation was the formulation of a mandatory policy which required the systematic introduction of jute and rubber swellants in the vapour phase, thus promoting their effective travel and sealing effects over several miles of mains, at minimum cost. Where necessary the treatment was supplemented by more localised treatments, but excavations on to individual joints were to be kept to an absolute minimum. Such a policy was re-endorsed by the Policy making committees of the British Gas Corporation, the successors to Gas Council.

4. Continuing Developments

One of the key aspects of the investigations was the search for an effective and economical jute swellant. In the days of manufactured gas, its residence time in water-sealed, low-pressure holders allowed the gas to achieve saturation, or near-saturation, with water vapour. Historically, with the introduction of dry, synthetic gas, some Regions or Boards introduced steam into the gas stream, in order to maintain the previous level of water vapour, a practice known as humidification.

However, the Department of Energy then required those Boards to reduce the calorific value on which it based its charges to a minimum level, consistent with the maximum possible take up of water. As the water content might vary, the Board could be losing revenue if the actual, thermal energy per unit volume of gas metered was greater than this minimum level. If the 'degree' of humidification could be controlled, the billing could be based on an agreed calorific value, known as the 'Gas Prescription' which was monitored by the Dept. of Energy at the Gas Board's expense, with fines payable if the "prescription" was violated. A less costly and more certain treatment was required!

Whilst it was known that Di-ethylene glycol (Anti-freeze), DEG, would swell jute fibres and commercial products to do just that were being used, the low vapour pressure of DEG was a drawback. Furthermore the distance that could be covered, from any point of introduction into the system, was limited to that over which the DEG could be sprayed; and there are practical limits as to how far a hose can be inserted into a gas main.

It was left to the rude mechanics at ERS to suggest, to their learned chemical friends at LRS, that other chemicals might have the same effect as DEG, on the cellulose fibres of the jute. The front runner to emerge was Mono-ethylene glycol (MEG), which fortunately had a significantly higher vapour pressure. Over many many months, the leakage rates through lead yarn joints, both new and exhumed, were measured, whilst air, alternately part saturated with MEG vapour was circulated around a test loop made up with the joints.

The tests reinforced field experience that it took many months for the MEG vapour to weave its spell and for the leak to reduce to a new, lower level. In general, the bigger the initial leak the larger was the reduction. There was no doubt about the effectiveness of MEG as a mains system treatment or that it needed to be applied continuously. On the credit side, there would be no reduction in calorific value of the distributed gas.

In order to achieve the maximum concentration of MEG vapour in the gas stream, it is necessary to vaporise the MEG. This can be achieved directly by, say, an electrical heater or by passing the gas through heated, but not boiling, liquid or by spraying the liquid into the gas main through 'atomising' nozzles, followed by evaporation drawing latent heat from the gas. There are many variations possible and a systematic evaluation of the performance and economics of them all was carried out. A design of a directly heated unit was licensed to a local company, Paul & Loughran Ltd. for which electrical certification for safe operation in a hazardous zone was obtained, by ERS, from the British Approval Service for Electrical Equipment in Flammable Atmospheres (BASEEFA). Units have been sold to most Regions as well as utilities in Austria, Japan and USA.

5. Post-script

The success of the company's leakage control policy has recently been demonstrated via work entrusted to ERS by the Engineering Directorate of Gas Business UK. In response to unsubstantiated claims from the 'Green' lobby, statistically significant, weighted samples of the distribution mains and services population have been isolated and their leakage rates measured. The test procedures and statistical analysis were vetted and commended by independant expert bodies. The results showed that leakage of natural gas ie of methane, a greenhouse gas, from British Gas transportation systems was well below that of Towns gas in pre-conversion days. The 'tour de force' which this investigation represented was masterminded by Dave Milne, Tom Archbold and Dave Casson.

As a rider to the leakage work ERS has recently completed a neat piece of detective work. Regions had become alerted to sporadic malfunctioning of metering equipment. The malfunctioning seemed to follow the application of a later generation of leak sealants, which were sprayed onto joints from within the main and which then cured anaerobically.

The chemical laboratory at ERS discovered, after much painstaking analysis, that some of this sealant was carried forward as a vapour and could deposit on the equipment. At this stage no harm was done but, with time, any subsequent deposition of MEG brought about a synergistic chemical reaction which damaged the equipment. Bill (Sherlock) Lunn and Peter (Watson) Hunter are to be congratulated!

Tony Neal testing a prototype 'GASCOPACT' outside ERS.

THE ADVENT OF POLYETHYLENE

by Lindsay Ewing

1. Introduction

It was in the mid 50's when the gas industry first utilised plastic pipes for the distribution of gas. The pipes were manufactured in polyvinyl chloride (PVC) materials but progression in the use of PVC distribution systems was inhibited by many problems and a majority of gas distribution engineers, as a consequence, developed strong reservations against the introduction of any plastic pipe system for gas applications.

When a Plastics Project Group was formed in 1967 at ERS under the leadership of Gerry Clerehugh, one of their first tasks was to overcome the perceived reservations about plastic materials and convince the engineers in distribution, of the benefits of polyethylene (PE) pipe as distinct from the disadvantages of PVC. In the following two year period strong links were forged with the twelve British Gas Regions in order to sway opinion in favour of the replacement of iron and steel pipe with non corrodible PE. At this time the thrust into plastics was the responsibility of Trevor Smith, Bob Moore and Lindsay Ewing, culminating in the successful installation of the first PE pipe and fitting system in 1969.

The early 70's saw the formation of a Materials Division, initially led by Tom Harrison and later by Roy Wilkins. A Plastics Group was established within this Division, headed by Lindsay Ewing with support by Martyn Greig, Trevor Stafford, Les Maine and Tom Hill. The brief was to guide the Industry from being a relatively minor player in the field of PE gas pipe technology through its transition to being the largest single user of polyethylene pressure pipe on a global scale. This is well illustrated by the almost trouble free operation of the 185,000km of PE mains and services currently installed in the UK. Such success has been largely due the high quality of plastics R&D undertaken at ERS which was firmly focused on clear end user requirements. The success in R&D has resulted in the development of Industry standards for PE gas pipe systems which have been adopted as the basis for international standardisation within ISO and CEN. Furthermore the acceptance of ERS as a centre of excellence in the PE pressure pipe business has been reinforced by the movement of several members of the Plastics Group into key technical and managerial positions in the plastic pipe industry. Ex ERS people who have successfully integrated into the plastic pipe business include Bob Moore, Dave Walton, Colin Burley and Alan Dickinson.

2. MAterial Development

The work on materials technology was mainly focused on the need to ensure that British Gas could purchase and safely use the most cost effective PE pipe materials capable of a leak free service life of at least 50 years in the normal distribution environment. Cost effectiveness was achieved by seeking the development and supply of suitable PE polymer from several world-wide sources which currently include Sweden, Belgium, France and Spain in addition to the UK.

For a gas distribution PE pipe material the critical areas of interest are its ability to achieve a minimum service life of 50 years at the maximum permissible operating pressure and in the event of unexpected premature failure, ensure that it is localised in nature and does not constitute a hazard to safety.

The long term durability of PE is dependent upon its resistance to the initiation and slow growth of cracks either from microscopic flaws inherent in the basic pipe product or more likely from defects introduced in the course of pipe jointing and installation. This mechanism of "stress cracking" has been the subject of extensive studies by ERS in order to guide polymer producers in the development of PE raw materials with enhanced stress crack toughness properties. As a result of this work, vast improvements in toughness properties were achieved which provided the opportunity to increase maximum allowable operating pressures from an initial 75 mbar in 1969 to a present day maximum of 7 bar without compromising the requirement for a minimum service life of 50 years. Novel testing techniques and equipment were also developed to enable the more accurate measurement of stress crack toughness to take place. The most significant change in testing methods was the use of notched specimens to accelerate crack growth rates and reduce test times as well as being more representative of the practical scene in which the external damage of pipe surfaces is always a possibility.

Previous ERS experience in the development of steel pipe materials highlighted the phenomenon of rapid crack propagation (RCP) and demonstrated the potential safety hazards to emerge in the event of RCP failure. Further work undertaken in the early 70's confirmed the susceptibility of PE pipe to RCP failure. A strain energy design theory was then developed which assumed the total strain energy stored in the pipe wall due to its internal pressure was consumed in driving a crack at high speed (300m/sec) along a pipe. The calculated crack driving force was equated to the basic RCP fracture properties of the material, determined from instrumented Charpy tests and a critical pressure, below which an RCP failure could be locally arrested, was obtained. Using an appropriate safety factor, it was then possible to identify the safe operating pressure.

This approach was first used in the design of a 355mm PE pipe for installation at Hampton Court in 1971. The theory was conservative and usually led to a substantial derating in operating pressure for some of the large diameter pipes. Later, a full scale RCP pipe test was developed that enabled the actual measurement of the critical RCP pressure for application in PE pipe design calculations and the subsequent removal of many of the pressure restrictions imposed on large diameter pipes.

The full-scale rig is located at Spadeadam because of the hazardous nature of the test and it is believed to be the only facility of its kind in the western world. Its flexible design has provided opportunities to carry out tests not only on behalf of British Gas, but also to cover other applications for the water and LPG industries. The full-scale test is however expensive and an alternative small scale RCP test has recently been developed by Imperial College on behalf of ERS. This version is intended for use on a more widespread basis to support the quality assessment of large diameter PE pipe production.

Jimmy Evans demonstrating Butt-fusion of PE pipe in the laboratory

Both the notched pipe test method and the RCP test procedures have gained recognition in international specifications. Several of the Plastics Group staff have been actively involved in preparing international standards and the CEN, ISO and ASTM standard authorities have incorporated the ERS tests in the official draft documents which are currently under consideration.

3. Jointing Technologies

Developments in jointing methods have proceeded in parallel with the work on basic materials. The overall objectives were the creation of simple procedures that were independent of the type of PE material used, thus permitting the supply of PE pipes from different sources and the creation of a highly competitive pipe supply market.

Initially heated tool socket and saddle fusion techniques were adopted for pipes up to and including 125mm; butt fusion was introduced for the larger diameters. The socket and saddle fusion tools supplied by manufacturers were each of a design unique to the particular system manufacturer, a factor that prohibited the free interchange of pipes and fittings throughout all Regions. A universal socket and saddle system was therefore designed by ERS and introduced to partially overcome such difficulties and now forms part of an ISO standard for PE pipe and fitting systems. However, Regional segregation of pipes and fittings still persisted because of material related jointing restrictions and further corrective measures were sought.

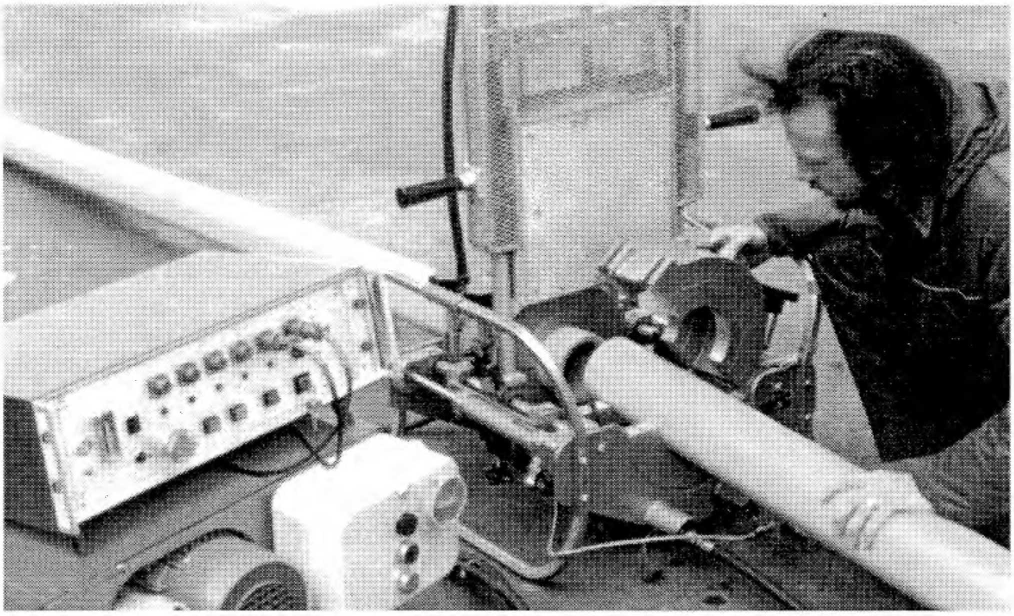
In consequence consideration was given, in 1975/76, to electrofusion as a possible solution to the remaining pipe segregation problems. Electrofusion was not a novel process since it was already established in Germany and Switzerland for some 20 years previously. The system had several problems but the overriding difficulty was one of fitting cost and the reluctance of UK fitting manufacturers to undertake the development of an alternative range of electrofusion fittings to meet the Industry's requirements. The development of the British Gas electrofusion system (Gascoil) was then initiated by ERS with the objective of producing an "as installed" cost effective system for distribution applications, that could be employed to joint any PE gas pipe using a common procedure irrespective of pipe material. The universal Gascoil system formed the platform for the development of the UK electrofusion industry involving five fitting manufacturers producing up to 2.5 million fittings per annum for the gas industry in sizes ranging from 20mm to 355mm diameter. The strength of the business has also enabled UK electrofusion technology to compete effectively in the world-wide international field against the established manufacturing bases in Germany and Switzerland.

Elecrofusion also offered a jointing procedure which was much less dependent upon operator skill especially when working in confined areas such as encountered in narrow trench situations. Further de-skilling of the operation was possible by the introduction of a fully automatic control system in which each fitting could be identified and the appropriate fusion parameters selected and implemented independent of operator influence. The principle of automation was also extended to butt fusion in which programmable electronic control of the key features of the butt fusion process cycle was achieved; data retrieval for quality control inspection by supervising Distribution Engineers was also provided.

Although major emphasis was given to the use of fusion jointing techniques in PE pipeline construction, the need to connect PE pipes to existing iron and steel pipes remained; an area that was dominated by the mechanical compression joint. In the early period of PE gas pipe development, the design of compression joints was often complicated involving several interchangeable parts leading to operator confusion during assembly. In addition doubt existed regarding the ability of some joints to resist the longitudinal forces often generated in practice as a result of internal pressure, thermal expansion and contraction effects and attack on the pipe by excavators! New concepts in joint design were necessary in order to take into account the long term creep and stress relaxation behaviour of PE materials, since these could have a significant influence on the capability of assembled joints to accommodate end loads.

Tom Hill assisting North Thames with a plastic insertion scheme – somewhere in the Metropolis.

The mechanical joints available in the early 1970s exhibited a limited end load restraint and were restricted in size to 63mm diameter, an unattractive feature for potential applications when size could extend up to 500mm. The problem was resolved by ERS technology which resulted in the development of the PECAT (Polyethylene Coupling and Transition) joint. The joint was simple in concept with only two components, an internal stiffener and an external compression ring; no rubber sealing rings were utilised. The widespread introduction of the PECAT joint throughout a size range 20mm to 800mm transformed the mechanical jointing industry by forcing a move into products designed for high end load restraint with a minimum number of jointing components. This was a rare occasion in which British Gas was instrumental in securing the supply of products with significantly enhanced performance at lower cost. The PECAT joint has enjoyed considerable success in use above and below ground; especially at PE to metal tie in connections on bridge crossings.



Trevor Stafford operating automatic pipe jointing equipment developed at ERS.

4. The Future

The work at ERS on plastic materials for gas distribution during the last 20 years has embraced many areas of activity including material selection and specification, fusion and mechanical jointing technology, installation codes of practice and Regional technical service. Technical support has been a major feature of ERS work, especially in the early years when Distribution Engineers already well established with cast iron and steel pipe materials were often reluctant to take on board the largely unknown technology of plastics. The move to polyethylene has been well justified as there are now some 185,000km of PE pipe in operation in the UK without significant problems.

The future development of PE pipe systems is likely to be less orientated to gas distribution. Exciting possibilities exist for the reinforcement of PE pipes to permit an increase in the maximum operating pressure from 7bar to 25bar for applications in the field of gas transmission and offshore flowline systems. The recent research undertaken by ERS to demonstrate the feasibility of jointing cross linked PE pipes by electrofusion and butt fusion, a feature that was previously dismissed by the manufacturers of cross linked PE pipe industry who for many years promoted the use of high cost compression fittings, has also opened many avenues of opportunity to exploit the superior qualities of cross linked PE; notably its resistance to failure at high (+100°C) and low (-70°C) operating temperatures. In this context possible areas of interest include hot water and district heating, the lining of high temperature offshore flowlines and the distribution of gas at sub zero temperatures for example in Siberia.

WHY DISTRIBUTION PIPES FAIL (THE PIPE LOADING UNDERGROUND PROJECT)

by David Casson

1. Introduction

On 21 October 1971 a very serious incident occurred at a modern single storey shopping block at Clarkston Toll, near Glasgow. A gas explosion occurred within unventilated voids at the front of the block, blowing the wall out and allowing the heavy roof (used as a car park) to crash down onto the shoppers and store staff below. Twenty one people were killed. A fractured LP gas main was believed to be the source of the gas and ERS was asked to investigate the failure by the Scottish Gas Board.

It rapidly became apparent that there were a large number of potential causes for the fracture and Dave Needham, who managed the investigation, instigated a wide range of research into cast iron pipe strength, including evaluation of loads on pipes from various external sources and loss of gas through fractures and corrosion mechanisms. It seemed that for a few months after the incident just about everybody at ERS was doing something connected with the incident, culminating in a Fatal Accident Inquiry. This rapid investigation on a wide front highlighted the lack of information and experience in a number of fields and spawned research at ERS for many subsequent years.

The biggest and longest running project to come out of the Clarkston Toll incident was the Pipe Loading Underground project; the purpose being to investigate the many reasons why gas distribution pipes fail, so that where possible, further pipe failures could be avoided. Many important spin-offs became apparent from this knowledge and ERS has become renowned inside and outside the gas industry for this research into the various fields of pipe strength and loading described subsequently.

The Engineers who have led the Pipe Loading Underground project team were:

1971 - 73	Colin Braithwaite
1973 - 75	Brian Flood
1975 - 78	Les Hinsley
1978 - 85	Malcolm Howe
1985 - 89	Malcolm Wayman
1989 - 93	Peter Hunter

2. The Bending Strength of Cast Iron Pipes

In 1971 when the project started, the vast majority of gas was distributed in cast iron pipes. Cast iron is quite a low strength material and is considerably more brittle than, for example, mild steel. Analysis of fracture statistics and early failure investigation reports showed that the vast majority of pipe fractures were in the circumferential direction, indicating that the pipes had been subjected to bending, rather than crushing stress.

Keith Hunter, who was the first Engineer to work on the pipe loading underground project, therefore started testing pipes to assess their strength in bending. This provided basic pipe strength data, against which the applied forces from number of sources could be compared. In this way, using evidence gathered on site, it was possible to assess what the most likely cause of failure for any given set of support and loading conditions. Subsequent pipe strength work was carried out with bend tests, conventional and specially developed tensile tests (Malcolm Howe's first involvement) and impact tests, to compare different pipe materials, quantifying their benefits and drawbacks and to allow the significance of typical defects to be assessed.

This work gradually led to the identification of the types and sizes of pipes which were causing the industry the most problems. When taken together with studies of broken mains statistics by Ken Bray, Tony Beeton and Dave Milne, in 1977/78, it became possible to structure a national mains replacement policy with the aim of reducing fractures and hence serious incidents.

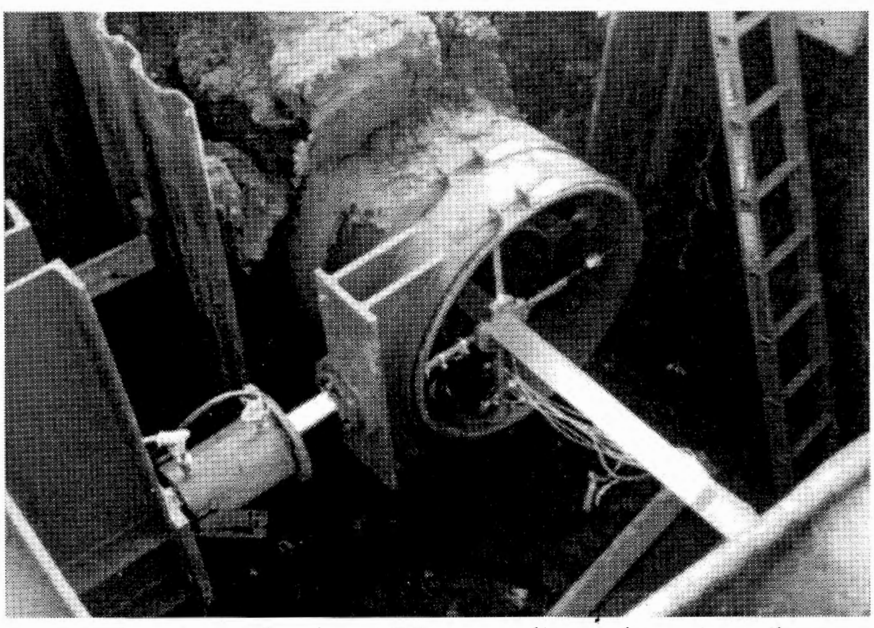
To assess the mechanism of failure of large diameter pipes, bend tests were carried out at ERS by Dave Casson, on fully instrumented 24 inch cast iron pipes. Theoretical analysis, using three dimensional finite element programs, was carried out by Denis Edward, to develop a general explanation of the effects of loading on large diameter pipes.

Studies were carried out by John Wilkinson and Dave Nelson, in the mid-80's into the stiffness of "flexible" pipe joints. This was needed to be able to predict the way that such joints alter the bending strength and pipe/soil interaction mechanisms being analysed by Geoff Leach at that time.

As a very broad generalisation, theoretical and practical testing confirmed that small pipes - say up to 300mm diameter were most prone to bending failures and larger pipes to crushing type failures resulting in longitudinal splits.

3. External Loads on Distribution Pipes

The Clarkston Toll incident highlighted the lack of detailed knowledge of the origins of the forces that act upon buried pipes. Most of the research knowledge that was available on this subject in the early 70's was American and concentrated mainly on the interaction between large diameter steel water carrying pipes and the surrounding soil at large depths of cover. Some work had been done in Britain at the Building Research Establishment and at the Transport and Road Research Laboratory but both tended to concentrate on problems associated with sewerage and/or drainage.



Loading tests on an abandoned 910mm pipeline to determine soil compressibility. Shown at the loading frame, hydraulic loading jack and instrumentation to measure lateral pipe movement.

While all this work provided valuable information, it did not match the pipe conditions most commonly met in Britain for gas distribution, i.e. small diameter cast iron pipes at shallow depth subjected to forces other than just the overlying soil. As a result, work was carried out to quantify the various possible types of load imposed upon distribution pipes.

Throughout all the Pipe Loading Underground project, pipe instrumentation design, installation and monitoring was organised by Gil Osborne and Eddie Falcus, together with a very loyal group of technicians who seemed to always end up working in foul conditions on site. As well as being experts with dynamic strain gauges, Gil and Eddie introduced the use of very stable vibrating wire strain gauges, which proved to be of great value in monitoring the slowly increasing strains which tend to result from many of the above sources.

As the project became involved with other major national organisations, it became necessary to expand the expertise within the team. In the early 80's, Ray Owen, a Civil Engineer with experience in road construction, Pravakar Nath, an expert in finite element analysis in Civil Engineering/Ground Loading, and Geoff Leach, a Geotechnical Engineer were recruited and provided a very powerful input into subsequent work involving pipe soil interaction.

The next section describes the investigations of the nine types of pipe loading.

Traffic When steel pipe was being considered for gas distribution use in the mid-70s, with the newly developed partial penetration welding techniues, concern was raised for the safety of the relatively thin walled, larger diameter pipes beneath heavily trafficked roads.

Theoretical analyses by Bill Richardson, in combination with "racing lorry tests" within the ERS site, were used to assess the deflections and strains caused by heavy vehicles. The tests involved driving a lorry, loaded with steel deadweights, repeatedly around the site, crossing the instrumented test trench as fast as possible on each lap. The predicted deflections agreed well with measured values and showed that thin walled steel pipes could be used beneath roads for gas distribution, without any special protective measures.

Much of the subsequent traffic loading work which was done in the late 70s and early 80s, was in preparation of a case against proposed EEC legislation for increasing the allowable axle loads for heavy goods vehicles. To this end, ERS leased a nearby abandoned road (Salters Lane), where more racing lorry tests took place, with higher speed crossings above instrumented small diameter (100mm) pipes.

Field trials in South Eastern, Northern and North Western Regions, supervised by Dave Bell in 1978 and 79, were used to quantify the pipe strains from actual heavy lorry traffic. Other tests on a buried main in Cumbria were used to assess the effect of heavy transporters carrying nuclear materials to and from the nuclear processing plant at Sellafield.

All this work, led by Malcolm Howe, was used in 1980, in a British Gas submission to the Armitage Inquiry set up to look into the effect of the EEC proposals on our roads and infrastructure. The submission raised the awareness of the Inquiry Committee into the damaging effects of heavier lorries on buried gas mains, particularly the effect of road condition, which in turn depends on axle loading. The Inquiry recommended that Britain should adopt lower axle loads than proposed by the EEC.

Backfill Loads While carrying out tests to measure various sources of loading on buried pipe, such as traffic loading, impact loading, tunnelling and deep excavations, the pipes, whether specially installed test pipes, or instrumented live mains, were always monitored during backfilling to assess the soil loads involved. It was established that in all cases of normal support conditions, the strains generated in the pipes by the backfill were small compared with the other potential sources.

Localised Ground Settlement Ground settlement can have many causes, but it was realised during the Clarkston research that if support beneath the pipe is removed over part of its length, the pipe acts as a bridge, supporting the backfill above it. This can invoke very high soil loads and these were first identified and measured at ERS by Mike Abrahams. A program, organised by Dave Casson, to quantify the forces more fully, was subsequently carried out in South Western Region. The results of this investigation were applied to all subsequent pipeloading analyses and incident investigations whenever ground settlement was involved.

Deep Excavations, Adjacent and Crossing beneath Gas Mains In 1974, ERS became involved in the implications of the rapid increase in sewer renewals throughout the country. Colin Braithwaite, then Group Leader in charge of the Pipe Loading Underground project represented ERS on a joint British Gas/National Water Council Working Party to create an agreement which would allow assessments of the potential risk to gas mains of ground movements caused by the construction of deep sewer trenches. When assessments showed that the mains were at risk, the Water Authority was to pay for the re-routeing or replacement of the gas main.

That was the theory ——! In practice, once the Water Authorities realised that this was going to cost them a great deal of money, they instituted a research programme with joint ERS/Water Research Centre(WRC) field trials to delineate the zones of influence of their excavations accurately, in the hope that this would reduce the compensation costs to them.

A large number of field trials, organised and monitored by Peter Hunter and Roy Chipchase, were therefore set up jointly with WRC, to verify the agreement conditions. The results of the field trials showed that the ERS predicted risk zones had been valid and highlighted our concern for the safety of gas mains, several of which were damaged during the trials. The main outcome was the adoption of the Model Consultative Procedure (MCP) in 1983, which has saved British Gas millions of pounds in mains replacement costs and has eliminated the need for lengthy and costly legal battles for reimbursement.

A direct spin-off of the research has been to provide pipe/soil interaction analysis computer programs, developed mainly by Geoff Leach. These have been used in many consultancy jobs for the Regions and in a number of incident investigations. The developing interest in pipe/soil interaction, required knowledge of soil parameters, which could only be measured using specialised equipment. To obtain this knowledge, the ERS Soils Laboratory was set up, in November 1978, under the leadership of Dudley Dickson. This facility played a vital part in the Pipe Loading Underground project and in Incident Investigation, and continues under the leadership of Sally Row, to provide an excellent soils testing service to ERS and British Gas.

Tunnelling By the late 1970's, following close on the heels of the deep excavations research work, ERS began to receive requests from the Regions for advice on the effects of sewer tunnels.

Again, with close liaison with WRC, field trials were set up to monitor the effects of sewer tunnels beneath gas mains. At the same time, considerable effort went into developing computer programs to:

(i) predict ground settlement due to tunnels and

(ii) translate that compound ground movement into pipe strains

The combination of theoretical/empirical predictions, backed up with actual ground movement and pipe strain measurements allowed a high degree of confidence to be attached to the predictive method. This is now used by the Regions as well as at ERS for assessing the effects of tunnels of all types.

Abnormal Loads Often when abnormal vehicles (weighing hundreds of tonnes) are moved from site to site, they pass over buried gas mains. Assessment involves calculating pipe stresses and devising protective measures such as layers of cushioning material temporary steel beam bridges above the mains, etc.

Explosive Blasting/Impact/Vibration Field trials were set up to monitor the effects of blasting near gas mains, with the aim of establishing acceptable levels of vibration in buried pipes. A maximum vibration velocity was derived by Peter Hunter and armed with that knowledge, advice has been given to Regions on many occasions as to the acceptable proximity and charge weight that could be permitted. Because of the ease of "cheating" by blasting operators, the Regions are usually advised to monitor vibration levels above their pipes .

There are a great number of other potential sources of impact forces on gas distribution mains and the research work has tended to be aimed at answering specific queries rather than to come up with an all-embracing theory. Typical problems assessed are the effect of falling masonry, pile driving and ground compaction activities and the outcome of blasting research can often be applied to these situations.

Temperature Variations Pipe fracture rates have long been known to increase during periods of cold weather and many theories and myths existed to explain this. Test work at Low Thornley, with large refrigerated enclosures, provided a simple explanation of the mechanism. As the temperature falls, cast iron pipes contract more than the surrounding soil and, if the pipe is "locked" into the soil by corrosion, it is then subjected to a tensile stress. This is of such a low level that it does not normally cause problems but if a pipe is close to fracture for other reasons, the small increase in stress due to temperature drop can be the final straw. This has put into perspective the significance of the increased breakage rates in winter, although there is little that can be done about it, without replacing the pipes.

Ground Moisture Variations Historical evidence also shows that in long periods of drought, the number of pipe fractures increases dramatically in certain areas. This became a very serious problem during the long hot summer of 1976, particularly in the South East. Research was carried out by Ray Owen at ERS and in field trials in the Regions to identify the mechanism and quantify the stresses generated in pipes by ground moisture changes. The tests showed that in moisture sensitive soils, ground settlements in excess of 50mm could occur at pipe depth in the immediate vicinity of trees. A pipe passing near to a tree was therefore subjected to varying amounts of settlement, producing bending stresses.

4. Concluding Remarks

Hundreds of ERS reports have been written by more than 30 ERS Engineers during the course of the Pipe Loading Underground project, but in the late 70s, Dave Needham and Malcolm Howe summarised the knowledge at that time in a paper presented to the IGE entitled 'Why Pipes Fail', for which they were awarded the Institution's Gold Medal on 27 November 1979. What is not so well known is the unpleasant fact that Dave Needham's house was burgled in September 1981 and his Gold Medal stolen. The story did have a happy ending, however, because three months later the police stopped a stolen car in Middlesbrough and found the medal in the glove compartment. It was returned to Dave via the IGE and he has managed to keep it safely ever since.

EXCAVATION AND REINSTATEMENT

by Ian Bell

1. Introduction

The Distribution developments group first began work on pipe installation techniques around 1968. At that time, excavation techniques utilised by the Gas Industry were relatively crude; pneumatic road breakers were used to cut the road surface, followed by hand digging to the required depth. Reinstatement was similarly basic, largely as a result of the Public Utilities Street Works Act of 1950 (PUSWA) which required all Utility excavations to be completed to a temporary standard only, with the Local Authority empowered to complete the work to a permanent standard, recharging their costs to the relevant Utility.

Excavation and reinstatement were gradually becoming high cost activities, although the standards achieved were often low, with much inconvenience to the general public. Criticism of Utility streetworks was starting to become widespread and the prevailing legislation served only to confuse the awkward question of responsibility. ERS recognised these problems well in advance of the subsequent Government committee of inquiry (the Horne Inquiry), allowing British Gas to establish a powerful, knowledge based, position and to make strong representations to the inquiry and substantial inputs into the resulting legislation and codes of practice etc.

2. Excavation

2.1 Initial Developments

The first steps in 1968 were to evaluate the standard equipment then used, which led to improved pneumatic road breakers being introduced and to an investigation of hydraulic powered breakers. Hydraulic power was more efficient and was inherently safer than pneumatic power in the event of failure of the supply hose.

Air compressors, pneumatic breakers and air lines etc had, however, been almost universal for many years and formal standards had long been established; all items were mutually compatible. Hydraulic powered breakers were relatively new and the establishment of a single standard within a conveniently short time was virtually impossible. This lead to the further development, in the mid 1970s, of customised team vehicles incorporating an integral hydraulic power unit, usually driven by the vehicle engine, to ensure compatibility. Hydraulic powered electric generators were also developed, to replace the generator often incorporated within air compressor trailers that were used at that time . A number of Regions introduced hydraulic power and adopted the standard team vehicle approach developed as a means to standardise hydraulic components. Much of this work was carried out by Eric Tasker, Alastair Robinson and Don Reid.

In parallel with the development of existing excavation equipment, a more radical and speculative 'rapid excavation' approach was investigated for small hole work, principally by Jon Wonham and Doug Wightman. A 'state of the art' rotary excavator was developed to allow a small rectangular excavation to be cut rapidly through a road structure. Essentially, the excavator was a vertical axis milling machine, attached to an extending boom mounted onto a specially developed vehicle. The toothed milling cutter was hollow to allow a vacuum system to suck up the spoil and transport it, through a duct running along the boom, into a hopper on the main chassis. The equipment was eventually developed into a working prototype that was capable of cutting through virtually any highway surface, at high speed. However, the clearance of certain soil types was problematic, boom vibrations were troublesome and the development of a version capable of cutting continuous trenches, rather than individual small holes, was not considered to be a realistic proposition. The project was halted, although much of the technology was utilised elsewhere.

2.2 Surveys of Regional Excavation Activities

During the development of the rapid hole excavator, several demonstrations were carried out for Regional engineers. There was much scepticism as to whether such highly mechanised excavation equipment would be acceptable for use in highways, particularly in urban areas. More conventional trenching equipment, including relatively small chain trenchers and wheel cutters was also demonstrated, with similar doubts expressed. However, Regional surveys were carried out by ERS personnel during the mid 1970s to investigate excavation requirements and workload etc and the resulting statistics were subjected to rigorous cost analysis. Overall, the scale and cost of excavation activities was found to be much higher than expected and ERS presented a series of seminars in each Region, which became known as 'Monty Needham's Flying Circus', named after David Needham, the Deputy Director responsible for the Distribution Division. Eventually, the need for mechanised excavation techniques became accepted by Regional engineers and practical field trials were then conducted, using proprietary chain trenchers, in urban roads throughout the UK.

2.3 Narrow Trenching

The excavation survey also showed that typical excavations were much wider than necessary, probably following past practices for cast iron pipe where access was required for jointing the pipe below ground; PE pipe was jointed above ground and actually required a trench width little more than the pipe diameter. Initially, developments were concentrated towards the most frequently used backhoe excavators, typically the ubiquitous JCB, and a special narrow bucket was developed to suit PE pipe. The narrow bucket was immediately successful and manufacture was licensed to a local company; around 600 were sold to Regions and contractors.

Narrow trenching – Inroad demonstration by Jimmy Evans.

Road saws were introduced along with the narrow bucket and, because of the high cost of diamond tipped saw blades and their fragile nature, it became necessary to investigate the basic principles of concrete and tarmac sawing. An instruction manual was produced, originally intended for Regional use, but it quickly became the definitive guide and was sold widely within the UK. Much of this work was carried out by Brian Smith, Doug Wightman and Ian Mearns.

Further development of the narrow trenching principle involved the general introduction of chain trenchers, although it was still necessary to develop small chain trencher attachments for backhoe excavators as a means to encourage the overall trend towards mechanisation. Surveys of all excavation equipment available in the UK were produced, covering backhoes, chain trenchers and wheel cutters of all sizes. Today, narrow trenching is standard practice and all Regions own and/or operate mechanical excavation equipment including a substantial number of major items of excavation plant up to 700 BHP.

Surveys have shown that the unit cost of excavation is now little more than it was almost 20 years ago; developments have effectively kept pace with the cost of inflation, saving some £80 to £100 million per year on the cost of excavation compared to the traditional techniques of the late 1960's, in addition to substantial improvements in quality and speed.

3. Reinstatement

3.1 Materials

Reinstatement research work began during the late 1970s, after the initial Regional workload surveys identified the high cost and questionable quality of typical reinstatements. At that time, an amendment to the PUSWA legislation, termed the 'Model Agreement' of 1974, was being introduced and the procedures instituted by this amendment formed the basis for the initial work. Conventional reinstatement materials were investigated to establish performance characteristics and baseline costs for the most common reinstatement options within the Model Agreement. This work was initially carried out at Salters Lane, near to ERS, in isolated sections of an A class road made redundant by a local by-pass. Later, the work was continued in a simulated trench structure constructed at ERS.

The work on reinstatement materials was supported by a full soil testing facility which, as mentioned elsewhere, was established in the late 1970s. Managed initially by Dudley Dickson, and more recently by Sally Row, a number of people, including Jackie Scott, developed new or modified soil testing techniques in that facility.

Essentially, traditional materials were found to be quite capable of achieving an acceptable reinstatement performance, but required a great deal of knowledge, experience and skill on the part of those doing the work. Special reinstatement training courses were introduced at the School of Engineering, giving basic training in highway design and materials technology, and practical sessions in the correct operation and maintenance of equipment.

3.2 Compaction Equipment

A wide range of compaction equipment was also evaluated and frequently found to be of poor quality or inherently incapable of achieving an adequate compaction performance. Traditionally, the assessment of any compaction plant was a long and exhausting cycle involving excavation, placement of test materials, compaction and re-excavation to investigate the state of compaction achieved. The procedure was usually repeated many times to investigate the effects of various numbers of compaction passes, material layer thicknesses and other material condition parameters.

New methods of compactor evaluation were therefore devised, involving the use of small accelerometer sensors to measure the compactor output directly, under standard material conditions, monitoring the amplitude, frequency and impact energy available for compaction. Ineffective compactors can now be identified relatively easily and some major manufacturers have utilised similar principles to improve their overall designs.

A new generation of low frequency, high amplitude vibrating rollers was developed, in co-operation with Bomag UK, for rapid trenching compaction where the limitations of vibrotamper compactors are most acute.

3.3 Compaction Monitoring

Traditionally, compaction was achieved by manoeuvring a vibrating tamper repeatedly over thin layers of material, within the confines of the excavation. The process was slow, uncomfortable, and physically demanding, such that operators seldom maintained their enthusiasm for long. Much also depended on the condition of the tamper, and of the material itself; the quality of compaction achieved was therefore often very low and no convenient equipment then existed to monitor the compaction performance achieved accurately. A small drop-weight tester called the Clegg Soil Impact Tester, originally developed and manufactured in Australia, had, however, shown some promise. microprocessor controlled version of the Clegg was developed, principally by Ian Bell and Alastair Robinson, with improved accuracy and operator independence. This British Gas version the Clegg meter is now manufactured in the UK, under BG licence, and is standard equipment in all Regions for compaction monitoring. More than 6000 have now been sold, including many to Highway Authorities, contractors, civil engineers and other Utilities etc with substantial royalty payments to British Gas.

3.4 Permanent Reinstatement

Due to the vagaries of the PUSWA street works legislation, Utilities had no rights to carry out the permanent reinstatement of their reinstatements. All works were therefore carried out twice, once at the initial reinstatement stage where work was completed using temporary materials, and again at the permanent stage some 6 months later, where the reinstatement was substantially re-excavated and reinstated for a second time using permanent materials. The Highway Authority was empowered to complete the permanent reinstatement, and to recharge their costs etc to the relevant Utility. The Utility usually completed the initial reinstatement, but often using low cost materials and questionable standards of workmanship, in an effort to minimise the interim cost, with the knowledge that the work would soon be repeated at the Utilities further cost.

Overall, temporary reinstatement became a high cost activity, because of the wastage in effort and materials, and the level of inconvenience to the general public and disruption to traffic became a matter of increasing concern. Additionally, the standards achieved were often low and many reinstatements remained in a temporary state for several years, rather than the required 6 months maximum, as Highway Authorities were unable to cope with the required Utility workload.

New reinstatement techniques were therefore developed to incorporate a reduced reliance on temporary materials, with minimal wastage of effort and materials, resulting in significant reductions in inconvenience to the public. The intention was to provide an immediate permanent reinstatement which would require no second visit. New methods of all immediate permanent reinstatement were successfully field trialled and are now increasingly being used by all Regions with substantial savings in costs. New materials were developed or promoted, as part of the general move towards immediate permanent works.

3.5 New Materials

Two types of new material were developed, one type to act as a sub-surface backfill and the other as a surfacing material. The sub-surface backfills investigated were foamed concretes which are based on blends of cement, fine aggregates and water, modified by the addition of foam similar to that used against aircraft fires. The resulting foamed concrete materials can be poured directly into an excavation in a single full-depth layer, without compaction, and will harden to an adequate match of the performance of granular materials traditionally used for sub-surface reinstatement. Foamed concretes were investigated by ERS, but most Highway Authorities remained reluctant to sanction their use in highway structures; their objections were seldom expressed in detail but were thought to be largely of a political rather than technical nature. However, by a fortunate combination of circumstances, a large pipelaying operation required the combination of narrow trenching and immediate permanent reinstatement, at maximum speed and with minimum inconvenience to traffic. Foamed concrete was considered to be the most reliable option and was applied with great success. ERS has since proved the performance of foamed concretes and promoted their use to the stage of national acceptance as reinstatement materials in footways and all road structures.

Conventional cold-laid bituminous surfacing materials rely on solvent additions that evaporate slowly with time, giving a poor performance, and are suitable only for use as a temporary surfacing. However, Bitumen Emulsion Macadams (BEMs) are bituminous surfacing materials that are cold-laid, yet are capable of giving a performance suitable for use in permanent reinstatements within footways and most roads. They have a storage life of 5 to 10 days, for use in place of conventional hot mixed materials which must be used within several hours of mixing.

BEMs can be used in most situations and are well suited to immediate permanent reinstatement work, as well as giving substantial environmental benefits compared with hot materials. ERS is at the forefront of the development of high performance BEMs for reinstatement use, having pioneered their development i the UK and and promoted their use to the stage of national acceptance as reinstatement materials in footways and most road structures. Much of this work was carried out by Ian Bell, Dave Boyes, Vic Braid and Alastair Robinson, with the valuable co-operation of many Regional engineers, including Fred Joynes of British Gas - Scotland.

Surveys have shown that, as with excavation, the unit cost of reinstatement is now little more than it was almost 20 years ago Developments have effectively kept pace with the cost of inflation, saving a further £150 to £200 million per year on the cost of reinstatement compared to the traditional techniques of the late 1960's, in addition to substantial improvements in quality and speed.

4. UK Street Works Legislation

4.1 Horne Inquiry

In 1984, concern over the state of Utility reinstatement works resulted in a Government appointed committee of inquiry; the Horne Committee were empowered to review all aspects of existing street works legislation. The committee received evidence from all interested parties and visited a number of establishments, including a major presentation at ERS.

Essentially, Highway Authorities lobbied for the right to carry out all Utility excavation and reinstatement work, at the Utilities cost, with utilities responsible only for the physical installation and maintenance of their apparatus: Utilities lobbied for sole responsibility for all aspects of their excavation and reinstatement work, with responsibilities for administration and inspection shared with the Highway Authorities.

The research programmes on excavation and reinstatement initiated by ERS allowed British Gas to present definitive evidence to the Horne Committee on the true scale and quality of Utility street works and the underlying causes for many of the problems, as well as the technical capabilities of Utility personnel and the potential of new techniques and materials. In 1985, the Horne Committee presented their report "Roads and the Utilities", strongly recommending that Utilities should be made responsible for all aspects of their street works. Government endorsed the Horne recommendations in 1986 and created the Highway Authority and Utility Committee (HAUC) with overall responsibility for generating the new specifications and codes of practice required by the New Roads and Street Works Act 1991. ERS played a major role in providing evidence in support of the new excavation and reinstatement developments and in ensuring that the improved techniques, equipment and materials were included within the new streetworks legislation.

4.2 Implementation

ERS has since provided substantial technical support in the introduction of new legislative requirements and the necessary training of personnel. Many aspects of the new national specifications and codes of practice have required detailed interpretation and implementation, and a substantial effort has been provided in technical support for British Gas Regions in resolving difficulties and disputes with Highway Authorities etc concerning the provisions of the new legislation and each parties' new found responsibilities within these.

Research at ERS is now concentrated towards the exploitation of new freedoms in techniques, equipment and materials to ensure a more cost effective achievement of the high standards of quality and workmanship that are required in order to satisfy the new responsibilities of British Gas and their commitment to customers.

TRENCHLESS TECHNOLOGY AT ERS

By Eric Tasker

1. Introduction

ERS first gave consideration to distribution mains and service installation problems in 1968. It soon came to be realised that, as at present, labour costs were a significant proportion of the pipework installation cost and an obvious target at which to aim cost reduction activity. The principal reason for this was that extensive manual excavation and reinstatement work was necessary in order to extend or repair the gas pipework system. The introduction of mechanical excavation methods was pursued but the major advantage of installing a pipe without excavation or reinstatement was seen as the ultimate goal.

2. The Super Mole

Work therefore began in 1968 on a project known as the "Supermole", headed by Doug Wightman, which was a device intended to tunnel underground and install the desired pipework. Extensive test facilities were prepared to test this device and also a range of other boring systems including the first mole known as the Kret tool, one of the first Russian mole designs to reach the West.

A number of design schemes were prepared and hardware produced as part of the Supermole project activity. However, at the time the National Transmission system was under construction and effort was required from ERS to ensure that suitable materials were chosen and construction techniques optimised. There was, consequently, a change in operational priorities and an associated switch in available resources, which prevented work on the Supermole from advancing beyond the initial design phase.

3. Installation of New Mains and Services

A major milestone in trenchless pipelaying technology was reached in the early 1970's with the arrival of the Grundomat mole in the UK, marketed by a company called Courtburn Ltd.

In 1974 a relative newcomer to British Gas, Eric Tasker, arranged one of the first demonstrations of the Grundomat mole which offered major performance improvements over the earlier designs of mole available at the end of the 1960's. As a result of this demonstration a great deal of interest was aroused within the Regions and encouraged by ERS large numbers of moles were purchased during the next few years. With the valuable co-operation notably from Robert Brown of British Gas Scotland and the late David Jameson of British Gas Southern, the use of moles as a routine low cost method of installing new mains and services became well established.

4. Mains and Service Replacement

By the late 1970's a major programme was underway to replace the stock of cast iron pipework with the newly developed range of polyethylene alternatives, and cost effective techniques were being actively developed using, where possible, trenchless technology. One of the most successful was a technique which became known as mains bursting or splitting, where a mole was pulled through the main being replaced cracking the cast iron pipe and pulling in the replacement pipework.

Although the use of a mole for this operation did not originate from development work at ERS, we were involved in test work to examine the possibility of damage from the broken iron fragments. A considerable amount of effort was put in at this stage by Vic Braid to assess this type of damage and offer methods of preventing it, which eventually lead to the adoption of a sleeve as a means of protection. Following along the theme of offering alternative solutions to a particular problem, an alternative to the use of moles for mains splitting was developed again by a relative newcomer to ERS, Geoff Mood. He developed, with the invaluable assistance of George More and Maurice Platts from the design office and Jimmy Evans and George Forster from the workshops, an alternative bursting system which operated from a compact hydraulic power unit and employed a cyclic radial expansion system activated by means of a hydraulic ram. This unit was much more powerful than the alternatives using the mole system and enabled even the strongest cast iron pipe joints to be split, an obstacle which had on many occasions prevented the successful completion of pipe replacement operation, using the mole powered systems.

The hydraulic split cone mains burster, as the device became known, proved to be very successful over an extended field trial programme carried out most effectively by Jack Doy, and attracted a commercial exploitation licence with D J Ryans Ltd,. later to be known as BERST Systems Ltd of Preston Lancashire. Under the terms of this licence the burster operated on many gas and water pipe renewal contracts within the UK and via an associated company, the PIM Corporation, it has been used successfully on contract work in America.

5. Extending the Range - The Rotamole and Rotasteer

By the mid 1980's British Gas had been involved in the regular use of moles for the installation of mains and services for 10 years. There was an increasing demand to employ this cost effective technique over greater distances (10 to 15 meters being typical at the time). This would allow even greater savings to be made particularly if the long range device could be steered to offset deflections induced by ground conditions or to suit the desired route of the pipework and to avoid obstacles in its path. In 1985 ERS was, therefore, set the task of developing a guided mole and Eric Tasker was responsible for directing a small team towards producing a prototype device as soon as practicable.

Testing the Rotamole in the field. Ike Williamson, Alan Redpath and Paul Robinson.

The programme required close co-operation between the mechanical engineers involved in the development of the steering system and control features and the electronics engineers who provided the expertise on location systems and various techniques required to control the device accurately under the ground. Peter Ward, who headed the team of electronics engineers, was provided with a desk within the mechanical engineering section in order to ensure the required co-operation between the disciplines was maintained at all times. As a result of this project team approach, rapid progress was made and by the end of 1987 a significant number of steering concepts had been evaluated, together with a wide range of location and control techniques.

A prototype steerable mole was controlled successfully underground over a run of 85 meters just in time for Christmas 1987, as just reward for the great deal of effort put in by the development team of engineers, aided by a loyal team of technicians including John Rose, Jack Doy, Colin Phillips, Peter Edwards, Alan Redpath, Paul Robinson, Bob Bibby, Bob Mitchell.

The New Year proved to be a significant one in the life of the project team; an alternative concept was developed to fulfil the guided mole requirement and a unique location system was developed. These developments were eventually to lead to the Rotamole system as we know it today. The change in the guided boring concept was necessary since although the earlier work had allowed us to demonstrate that a guided mole could be produced, the instrumentation and mechanism were very complicated and it was thought that in that form it was unlikely to be an operational or commercial success.

The Rotamole system employed some of the steering concepts developed during the earlier work but was designed to produce a small pilot bore which could be expanded as required to suit the pipe being installed during the second operation called backreaming. A 45mm Grundomat mole was used to punch a hole through the ground assisted by the thrust from a surface mounted drilling rig, which provided pull and push forces together with rotation.This concept was evolved during discussions within the project team, which at the time included Vic Braid, Peter Ward, Dave Nelson, Andy Russell, Bill Appleby, Mike Sullivan and Alan Dickinson, the last named having joined the team from the Materials Division seeking new challenges and new frontiers.

The solution of how to build in a reliable location system into such a confined and aggressive environment was solved by pioneering work carried out by Alan Dickinson around an idea of Len Browns which used a rotating magnetic field as a means of positional identification. Alan developed the first computer programme which enabled the depth and plan position of a rotating magnetic source to be determined. Later this was further developed into the Rotasteer location system. As confidence in the concept grew Regional field trials were planned and operational experience was rapidly accumulated. A new member joined the team, Doug Rennison formerly with the OLIC operation, and strengthened the field trial team and the production and mechanical engineering skills within the team.

As with all new developments Rotamole had its fair share of problems one of the major ones was failure of the drill rods, a critical component within the Rotamole system. A major improvement in drill rod reliability was achieved through the efforts of Andy Russell in terms of design improvements and production procedures. Having achieved a significant improvement in reliability, a major field trial programme began in several Regions, with rigs procured by OLIC at Cramlington. This arrangement allowed ERS to continue with the development programme.

In 1990, following a seminar, hosted by ERS, for those Regions with operational experience of the Rotamole system, a further increase in the number of rigs was authorised eventually bringing the total number in use to 36. Whilst the production of these rigs was carried out at OLIC at Cramlington, operator training was the responsibility of ERS until about September 1990, when a Regional centre was set up within British Gas East Midlands.

6. Rotamole Mark II

By early 1991, operational experience was indicating that the Rotamole system offered major cost savings and hence any improvements in performance would further increase these savings .

Consequently, spurred on by the customers' requirements, as well as an Increasing number of rival systems on the market, the challenge had to be met. The Mk.II system was developed to meet this challenge and was launched in 1991. The Mk.II system used a Hammer Drill in place of the Grundomat mole during the pilot boring operation and a revised backreaming system which used a conical air blown reamer, called a Rabbit, developed from a 'Regional Ideas Suggestion Scheme' proposed by the British Gas South Western Rotamole team. Together with an increase in power from the rig and strengthened drill rods the Mk.II system delivered the required operational performance over a wider range of ground conditions.

A member of the Electronics team, Phil McEonnell, made a major contribution to the development of the detection system, being responsible for work which lead to the Digital form of the Rotasteer system. This resulted in a major improvement in the operational convenience of the system, reducing the detection times and allowed detection depths to be increased.

The electronics were rehoused in plastic mouldings which gave a very professional look to the system, the mouldings were developed following the valuable efforts of Dave Bell and Fletcher Dobson from the Design Section.

7 Marketing the Rotamole

The success of the Mk.II system attracted the attention of the Steve Vick International organisation, a company well established within the gas supply business world wide. A marketing licence was negotiated with Steve Vick International for the Rotamole system and to date rigs are in operation in Europe, North America and Japan, with potential interest generated in many other markets world wide.

The widespread use of trenchless technology in Europe and world wide has reached its current level of market penetration and technical achievement due in no small way to the pioneering work carried out at ERS and subsequently within British Gas as a whole. Although markets would have been created eventually and product performance would have improved it is doubtful if all this could have been achieved within such a short timescale without the foresight ERS had about the benefits this technology could offer British Gas and other Utilities.

DISTRIBUTION INCIDENT INVESTIGATION

by Ian Bell

1. Introduction

From the very start, the provision of an incident investigation service was an integral part of John van der Post's research philosophy of striving for the closest possible contacts with field operations. Initially reforming plant problems were investigated and then, with the change of policy in 1967 (see Part I), the focus shifted to transmission incidents. It was at this early stage that Dick Knight came to look after the metallurgical aspects of incident investigation, a subject to which he was to devote just about the whole of his subsequent professional career.

In parallel to these investigations ERS, however, also gradually became involved with distribution related incidents, although early investigations were on a fairly 'ad hoc' basis. It was, in fact, some years before a formal arrangement was introduced and a permanent team set up.

2. Clarkston Toll

A very serious incident occurred at Clarkston Toll, near Glasgow, in 1971, in which gas, escaping from a fractured main, collected within an unventilated void beneath a shopping precinct and ignited; 21 people died in the subsequent explosion. ERS was requested to assist with the investigation. David Needham attended the site and represented ERS at the subsequent public inquiry. As described elsewhere in Part III, a number of significant findings required further R&D assistance, including improved detection and measurement of escaping gas, and an explanation of the newly identified phenomenon of fissure corrosion in cast iron.

A further consequence of the Clarkston Toll incident was the decision that ERS should set up a more formal arrangement for providing assistance to Regions in the investigation of distribution related incidents. A distribution incident team was then set up, comprising Colin Argent, Colin Braithwaite, Dick Knight and Neville Robinson. At this stage, the team was unofficial, and arrangements for call-out were informal. Regional requests for assistance with distribution incidents then steadily increased, and ERS gradually built up expertise and confidence.

The two most significant incidents investigated over the next 3-4 years were at Coleford and Sunderland. The Coleford incident occurred in 1974 and was due to the fracture of a gas main which had been undermined due to the effects of an adjacent deep excavation for the installation of a sewer. The escaping gas tracked into a nearby property (which, ironically, did not have a gas supply) and ignited before it could be traced, destroying the property. This again lead to the initiation of research work, described elsewhere in Part III, on the risks to gas mains from adjacent deep excavations.

In the incident at Sunderland, some months later, gas leaking from a fractured main found its way into a telephone exchange. Again, the gas ignited before the escape could be traced and the telephone exchange, which had just been constructed at a very substantial cost, was totally destroyed. Both incidents gained much media attention and raised many questions regarding the integrity of the gas distribution system and the behaviour of escaping gas.

As a result of these incidents, ERS also began work to study the movement of gas below ground and the passage of escaping gas through property walls, with special emphasis on the possible tracking of gas along the route of existing underground pipes and cables, and penetrating into properties via unsealed gaps around pipe and cable entry points below ground. Later, ERS progressed the development of above-ground service entries and sealed sleeving designs for those properties where the gas service entry point remained below ground. Both of these developments are now standard practice for British Gas service installations.

3. Establishment of Distribution Incident Service

By 1975, requests for assistance in distribution incidents were occurring almost monthly and the Distribution Engineering Committee (DEC) recommended that a formal incident investigation service be established at ERS. In July 1975, the Production and Supply Policy Committee (PSPC) determined that British Gas policy should be to establish the true cause of any incident, wherever possible, with a view to establishing evidence or information that could be of value towards:

1. The prevention of further incidents.
   Incidents were analysed in order to identify any recurring factors or other information leading to improvements in component specifications, operational codes of practice, leakage control and other policies.

2. The establishment of definitive evidence.
   Investigations could be required to provide evidence for any formal proceedings, public inquiries, coroner's courts or other litigation, to support British Gas or to pursue a claim against other parties.

3. The consolidation of confidence in the Gas Industry
   Investigations were intended to demonstrate the professional responsibility and technical ability of the Gas Industry so as to retain the confidence of customers and the public at large.

Thus, the ERS distribution incident investigation team was formally set up, with the remit to assist Regions, at their request. The term 'incident' was defined to cover any event resulting in one or more of the following:

1. Loss of life or significant injury to any person.
   Significant injury, as originally defined, included minor burns or any more serious injury.

2. Significant damage to any property.
   Significant damage, as originally defined in cash terms, has not survived inflation and is now wholly discretionary.

3. Loss of supply/pressure to a significant number of customers.
   Significant number of customers, as originally defined, was 200 or more, but is now also a matter of discretion.

Neither the investigation criteria nor the incident types were intended to be exclusive or exhaustive. An additional category of incident soon became accepted, as far as ERS was concerned; that of 'operational accident' or any hazard to health or safety resulting from any unusual event occurring during maintenance, pipelaying or construction activities carried out by direct labour or contractor. Under these circumstances, no actual accident or incident needed to have occurred. However, the decision on whether to call out the ERS distribution incident investigation team was made by Regions, and their interpretation of what constituted an 'incident' was somewhat variable.

A voluntary eight man distribution incident investigation team, led with great enthusiasm and commitment by Les Hinsley, was then established. Apart from Les, the other members of the team were Colin Argent, Arthur Brown, Dave Casson, Ian Glasgow, Dick Knight, Bill Richardson and Neville Robinson. On request, a team of two experienced investigators and an incident kit of specialist equipment would be dispatched to any incident. Team membership remained a part-time activity only, because of the sporadic nature of incident occurrence.

The formal call-out was originally made by a Regional Director of Engineering, or, on occasion, by a Regional Solicitor. Later, in order to protect the confidentiality of findings etc., the call-out became the responsibility of a Regional Solicitor alone. Effectively, the ERS team was called in to investigate, and provide evidence, on behalf of a Regional Legal Department and all subsequent reports and data then became subject to a legally protected confidentiality.

4. King Inquiry and Expansion of Incident Team

During the seven day period between 28th December 1976 and 3rd January 1977, there was a series of four serious gas explosions, at Bradford, Bristol, Brentford, and Beckenham; three of the explosions occurred within less than 36 hours. The incidents received a great deal of media attention and led to a Government committee of inquiry, chaired by Professor King of the University of Manchester Institute of Science and Technology (UMIST). The King Inquiry found that there was no common cause for the four gas explosions in question, that major failures of gas mains were relatively rare and that ignition of gas escaping from a major failure was virtually inevitable. The inquiry concluded that the safety standards of British Gas were undoubtedly high and the Company's safety record compared well with those in other countries.

Multiple unrelated incidents, occurring within a short time period, had previously been considered to be highly unlikely; no such events had ever occurred in the UK. The fact that these events also took place during the Christmas holiday period presented additional difficulties. The incident team, in fact, investigated a total of 10 incidents in the month between 4th December 1976 and 4th January 1977. In consequence it was decide that the incident team should be strengthened, and within a few months the team was increased to eighteen members.

Incident attendances averaged at 20 call-outs per year from 1977 to 1984. Throughout this period, lines of communication with each Region were strengthened and consistent methods of site and laboratory investigation were developed. Additionally, a formal 24 hour standby rota system was introduced, telephone pagers being issued to provide a more efficient call-out procedure.

5. Current Procedure

Based on the above changes, the current procedure provides a two man 'duty' incident team on permanent standby. The team, fully equipped, can be dispatched within 30 minutes from contact, if necessary. The target is to attend at the incident site within 6 hours of receipt of the call-out and this has been met on most occasions.

The incident team usually travels direct to the incident site, and contacts the senior British Gas representative. At this early stage, incident sites are often under the charge of a fire officer, or a representative of the Health and Safety Executive (HSE); permission is often required before the team can gain access to the site and formal declarations of presence are occasionally required. The HSE have powers to conduct their own investigations and incident teams have often been formally 'seconded' to act directly on behalf of the HSE. In Scotland, procedures are somewhat different; the Procurator Fiscal has powers of investigation, and he can subpoena assistance or attendance, respectively.

The main objectives of site investigations are to locate the source(s) of escaping gas and determine the probable cause(s). Where possible, the path of gas entering relevant property is traced and, where an explosion has occurred, possible sources of ignition are usually identified. The conclusion of most incident investigations is the identification of the most likely sequence of events that would produce an outcome most closely matching the known facts relevant to the incident.

Following experiences obtained from many cases of litigation, two separate incident reports are produced. The first report records the site and other factual evidence obtained from site investigations and subsequent laboratory examinations. The second report records the opinion of the incident team, including their interpretation of evidence and presents the most likely sequence of events. The final 'factual' report is usually available within three to four weeks. The 'opinion' report is produced only at the request of the relevant Regional Legal Department; depending on the course of any litigation, the 'opinion' report may be required up to 7 years later.

6. Scale of ERS Involvement

Since 1968, ERS has investigated more than 250 incidents, some 80% of which have involved broken gas mains. Of the remaining 20%, 9% have resulted from gas service pipe failures, and around 11% have been from a whole range of miscellaneous events. Investigations have been carried out in all manner of properties, including agricultural and factory sites, a wide range of commercial premises, shopping precincts, many individual shops, Government offices, several banks, two London Underground Tube stations, two churches and a crematorium. However, the majority of incidents have occurred within residential properties.

The incident team was led by Les Hinsley between 1975 and December 1993, apart from a one year period when Neville Robinson stood in. In terms of their duties, Dave Bell, Les Hinsley, Dick Knight and Peter Ward have probably recorded the most court appearances, although Ian Bell has spent the longest, continuous, time in a witness box representing British Gas and is also the only team member to have been instructed by a Regional Solicitor to hide behind a wall to avoid meeting an HSE inspector, as ERS investigators had reached the site earlier than expected and before a formal declaration of attendance had been notified to the HSE. However, the unsung members of the incident investigation service are the ERS laboratory technicians, particularly Eddie Duerdin and Doug Keenlyside from the metallurgical laboratory, Eric Johnson and Brian Evans from the metrology department and Peter Nolan from the non-destructive testing laboratory; all have provided detailed measurement and skilled analysis on countless occasions, invariably at short notice and always in a rush. Their contributions deserve full recognition.

More than 40 engineers and technicians, from virtually the full range of engineering disciplines, have been involved in the operation of the distribution incident team. In addition to providing the incident service, all have gained valuable knowledge which has directly benefited their main research and development activities. Similarly, incidents resulting in formal proceedings etc. represent major occasions when R&D staff can demonstrate their professional expertise in the public arena. Perhaps the most important 'spin-off' provided by incident investigations is the operational information that can be obtained by examining equipment failures. Where common factors have emerged, these have led to significant changes in British Gas policy, and new or amended codes of practices, component specifications and maintenance practices for critical items of plant. The incident information database continues to provide detailed information and feedback that is utilised in the development of British Gas policy on system design and safety assessments, mains and service replacement policies, and leakage surveys etc. British Gas evidence submitted to a number of Government committees of inquiry, including the Armitage Inquiry on traffic loading, the King Inquiry on gas explosions and the Horne Inquiry on utility street works, has also relied a great deal on information obtained from incident investigations.

7. Overall

The events leading up to most incidents have been satisfactorily accounted for; only a very few remain unexplained. Most incidents have been straightforward, resulting from very simple events and human errors, albeit under circumstances or with coincidences that have often been extremely unlikely; only a very few incidents have required 'clever' deductions to determine the cause. Experience has shown that it is relatively rare for any failure to result from a single cause, although there is often a single major source of pipe loading, with several other factors effectively providing the 'final straw'.

Many incidents have resulted in litigation, with actions often proceeding many years after the incident itself. To-date, ERS incident team personnel have given evidence, as expert witnesses, in many court cases, and have submitted a great many technical reports which formed the basis for out-of-court settlements, thus avoiding the need for further legal action by British Gas, in pursuit of claims against other parties. Such evidence, and reports, have been accepted as representing 'independent' expert testimony, even though the witnesses were British Gas employees at that time and British Gas was one of the parties involved in the litigation or settlement.

GAS DETECTION

by Howard Scott

1. Introduction

During the 1970's, the Company was introducing natural gas as a substitute for town gas, and it is probable that ERS would have entered the field of Gas Detection instruments at some time in the early years of that decade. However, in 1971, a serious event occurred in Renfrewshire, now known as the "Clarkston Toll incident", where the explosion of gas leaking from a broken main into the basements of nearby properties, caused 21 fatalities. A small team from ERS were involved in the investigation, and Dave Needham brought back to ERS, for assessment, a number of Shorts Indicators, which were the "Industry Standard" instrument for gas concentration measurement at that time.

The instrument had been in use for many years, and gave a read-out proportional to the partial pressure of hydrogen in Town Gas, which diffused through a porous plug. Gas concentration was inferred from the final reading of the pointer, and the rate at which it rotated around the scale. Natural Gas versions were also available, in which Methane diffused through the porous plug. For Natural Gas, however, accuracy and repeatability of the measurement were such that a replacement instrument for use by the craft work-force was required; so gas-detection investigation at ERS was born.

2. 'GASCOSEEKERS'

In 1972, John Newcombe, Mike Sporton and Tom Archbold, with their backgrounds in electronics, instrumentation and physics, began work with operational staff in the Regions to write a specification for an instrument able to measure gas (methane) concentrations unambiguously, from 500 ppm to 100% gas (in air). Discussions with the Safety in Mines Research Establishment (SMRE) led to the selection of up-to-date catalytic sensors, known as pellistors, for the more demanding lowest concentration. These consist of a platinum heating coil encapsulated in an alumina bead on the surface of which is deposited a thin platinum catalyst, which changes its thermal resistance when in contact with methane (see illustration). The heating coil controls the temperature of the bead to a constant value. The current required to achieve this, being related to the methane concentration, is displayed on a calibrated meter scale. SMRE built a first prototype, to an ERS specification, for bench testing and several manufacturers were invited to design and manufacture a pre-production batch of fifty, for which they were required to obtain appropriate safety certification.

Two manufacturers were selected for field trials in the Regions, and when one of them, Mine Safety Appliances (MSA), dropped out, Gas Measurement Instruments (GMI) became the only supplier and produced 20,000 instruments between 1975 and 1985, when a new specification was written. The instrument was amongst the first to carry a GASCO prefix (which identified the design as being of British Gas origin), being widely known as "the GASCOSEEKER".

GASCOSEEKER, Mk I, became the recognised instrument for use by the Company's work-force when investigating gas leaks from premises or from the Distribution system, and it is a testimony to the robustness of the design that it was bought in such large numbers over such an extended period. During the lifetime of the design, the only modifications required were a water check valve and then a hydrophobic filter, to prevent damage to the instrument by water, often present in bar-holes, being drawn up during the gas sampling process; and a change in the type of battery specified for operation in abnormally cold weather, when a zinc-carbon type could not develop the voltage required.

After a decade of service, however, the original design, basically unchanged, was becoming long in the tooth and some components were becoming difficult to obtain. The manufacturer recognised the need for a new product as early as 1981 and, by March 1982, they produced a concept design which was sent to Tom Archbold for information. On the basis of this, and because of known weaknesses in the original design (principally the leather carrying case which was prone to failure and was expensive to replace, and the moving coil meter display system), a working party, in which Tom Archbold was actively involved, was set up to write a new specification. Its objective was to reduce the cost of ownership, by adopting a modular design philosophy to simplify repairs, and to simplify routine maintenance by taking advantage of automatic test and calibration techniques (the gas detection technology, based upon pellistor techniques described above, remained unchanged).

In 1983, a draft of the specification of GASCOSEEKER MK II, known in the trade as INQ3!, was released to potential manufacturers and, after extensive consultation, three of them undertook to supply designs for evaluation at their own cost and risk. Evaluation of the three designs commenced at ERS in 1987, with the GMI instrument being the only one to survive the process. The evaluation was followed by a full scale Regional field trial, and by 1989, the first GASCOSEEKER MK II's were entering service. There are now (1993) 7,500 in use, a number which is increasing at the rate of 2,000 to 3,000 per annum.

A parallel activity was taking place in formulating a maintenance policy for the new instrument and, in 1989, the production of a maintenance standard, INQ5, was started, together with a specification for an automatic system for checking the function and performance of the instrument at British Gas depots and for an Information Management System (IMS) which allows the automatic storage and up-date of all GASCOSEEKER Mk II maintenance records. These documents were completed in mid-1991, Depot Checkers began to enter service in 1991 and, currently (1993) a total 170 are in use in the Industry. The first of the IMS's were delivered at beginning of 1993 and, currently 11 are in service. The new instrument, together with its associated automatic maintenance and calibration system, is gradually replacing the MK I's as they reach the end of their useful lives and the Company is now reaping the benefits of reduced ownership costs.

3. Leakage control surveying

As described elsewhere in the History, the change to natural gas caused the joints in gas mains to dry, shrink and allow higher levels of gas leakage. In these new circumstances, the Company could no longer rely upon public reports of gas escapes, but had to search for evidence of gas leakage by routinely surveying the gas mains. Mains survey by a bar hole and combustible gas indicator (such as GASCOSEEKER) was impractical - it was exceedingly slow, and bar-holing caused significant damage to the footpath and carriageway.

Initially, instruments capable of detecting hydrocarbons in air at concentrations of just a few ppm were used, with the dominant method being the Flame Ionisation Detector, or FID as it became known. The principle of FID is that a current passing through a hydrogen flame is proportional to the hydrocarbon content of the surrounding atmosphere supporting combustion and the instrument uses air drawn continuously, from ground level over the line of gas main, which is then analysed for the presence of methane. FID's were either a man-portable instrument, or a motor-vehicle mounted unit with a sample line connected which was carried by a man on foot. This method was generally referred to as a foot survey. Survey rates increased, but the time taken to cover the whole distribution system was still too long to enable District Engineers to assess the growth in leakage from the distribution system on a regular basis, or to assess the overall effect of distribution system treatments for reducing leakage.

The solution, proposed by Mike Sporton, was to adopt and adapt a technique from The United States, where vehicles fitted with FID's patrolled city centre areas in winter months looking for large gas escapes caused by ground heave. Consequently, in 1974, the patrol survey concept was born.

Surveying roads containing gas mains, at speeds of up to 20 mph, offered the capability to monitor a large part of a district in a single shift. The initial surveys were done at night to overcome the problem of sensitivity to vehicle exhaust emissions. Regions and Contractors suggested innovative ways of recording the data. For example, recording charts driven in proportion to the vehicle speed and at a scale corresponding to the Ordnance Survey mains plans.

Early in the trials of the patrol survey method, it became clear that different patrol survey vehicle systems produced varying levels of response to the same leakage source. ERS was called upon to investigate, and the reason for the variability was quickly identified, by Richard Thomas and George Crooks, as an incompatibility between the relatively slow sampling time of the FID detector and the speed of the patrol survey. Consequently, detection of gas by patrol survey was critically dependent upon the dynamic response of the whole sample collection and analysis system. Fond imaginings of building a wind tunnel were thwarted when, in 1975, ERS demonstrated that the dynamic response of any system could be determined, in a laboratory, by injecting a known volume of gas by means of a plastic syringe and a length of plastic tubing and, in 1975, testing of contractors vehicles started.

From the various detection systems which had already been bought and were being operated by the Regions at that time, ERS quickly established the range of dynamic responses, and developed a small electronic black box to correct for the performance variations. By 1976, a standardised response to known gas concentrations was obtained, and the low level noise on the recorder base lines was eliminated. This work led to the ability to set up the detection equipment so that a gas escape on the threshold of detection by the human nose, which is some hundred times below the lower explosive limit, would produce a full-scale response on the recording system.

In 1977, the writing of a British Gas code of practice and specification relating to patrol survey (S 58) was started and by 1983, Version (viii) of the document had become BG Engineering Standard PS/E22. ERS continued to be involved in patrol survey work and in 1989, co-operated in a joint working group, with the Regions, to revise PS/E22 to include the concepts of trigger surveys (where surveys are initiated by events known to produce a high incidence of leakage) and priority zone surveys (where areas with known high risk factors are surveyed on a planned basis).

International recognition of the work led, in the late 1970's and early 1980's, to involvement with ICS in the designing and building of patrol survey systems, including vehicles and training in BG leakage survey policy and operational procedures, for Italgas and Osaka Gas.

Today, many miles are covered by patrol survey vehicles and the success of the method is due in no small measure to the efforts of ERS in identifying the causes and in implementing solutions for the initial problems, which allowed the performance specification to be met. Because the system responds to any hydrocarbon, the problem of false indications due to vehicle exhausts is a major technical problem. The development, however of in-line exhaust gas oxidisers, which use the same catalytic converters now fitted to motor vehicle exhaust systems, have gradually reduced the problem to acceptable levels.

4. 'GASCOPROBE'

During the 1970's, there was one operational problem which Regions found difficult to contain. Gas which escaped from the mains system would often track, preferentially, into Post Office telephone ducts and sometimes migrate to jointing chambers, where a real hazard to GPO operatives working in the chambers, could result.

Dick West realised that the way to tackle the problem was to locate the position where gas was entering the ducts as an aid to locating the point where it was leaving the Distribution system. A detector, which became known as the GASCOPROBE, was designed for towing through the ducts and it incorporated a semi-conductor sensor which responded to methane together with a signal generator and transmitting aerial to identity its position.

Although the GASCOPROBE was successful in clearing the backlog of PO ducts containing gas which could not be used, the complex procedures, requiring the presence of PO and British Gas staff, caused the instrument to become a last resort for locating the culprit leak. Regions still have units, but they are used infrequently.

5. Optical gas-detection

In 1981, Mike Sporton reported the development, in the US, of a portable ppm gas detector based upon the selective absorption of infra-red by methane. This triggered a growing interest, by David Pinchbeck, in the opportunities for new measurement techniques offered by optical technology. Advantages, such as intrinsic safety, distributed sensing and potential wide area coverage for gas detection, are important considerations for the Company.

By 1982, the first optical fibre system for detecting spills of liquid gases was installed, experimentally, on an ethylene storage tank at Partington. The success of this venture quickly led to the widespread use of such detectors on British Gas LNG holders, where leak detection is essential for safe operation.

The high maintenance costs of pellistor based gas detectors on offshore platforms encouraged David Pinchbeck to develop a prototype line-of-sight methane detector using a dynamically operated Fabry-Perot filter made by GEC. As a founder member of the Optical Sensor Collaborative Association (ISCHIA), at little cost to British Gas, he promoted several valuable external studies in the field of optical gas-detection, notably the use of evanescent wave absorption (i.e. the use of light energy leaking from the confines of the optical fibre), for the distributed sensing of hydrocarbon gas. The advantages of optical sensors over conventional methods, should lead to extensive applications within the Company's operations in the coming years for the implementation of cheaper and more reliable gas sensing systems, not just for hydrocarbons, but for toxic gases such as hydrogen sulphide for which detectors are essential for the safe development of resources such as Karachaganak.

THE GAS CONTROL MODULE

by Ken Wood

1. Introduction

It is common practice for natural gas supply companies to move gas at high pressure through areas of low population and reduce the pressure in stages as the pipelines pass through areas of higher population towards the customer. These pressure changes are made at pressure reduction installations, usually called governors, consisting of an often complex arrangement of valves, pipework and associated instrumentation. The overall purpose is to ensure that constant outlet pressure is maintained irrespective of gas demand. The governor is usually enclosed in a brick or steel building, often some distance from the gas main itself.

British Gas operates about 20,000 governors at inlet pressures up to 2 bar, mainly in urban environments providing the last stage of pressure reduction before the gas reaches the customers.

2. Historical Background

Siting governors in an urban area is not easy. They are regarded as unsightly, to be concealed wherever possible, and suitable land can be difficult to find in congested areas, often leading to sites being some distance from the technically most suitable location. Furthermore, unattended buildings often attract vandals.

Most of the operational problems relate to leakage from the many joints, component failures and noise. Maintenance must be carried out on-site whatever the weather conditions. In normal weather the environment is not ideal for stripping and re-building delicate control equipment; in bad weather even greater problems are experienced. Regular painting and repair of governor buildings is an additional expense which contributes nothing to the prime purpose of the installation.

Many attempts have been made over the years to eliminate the problems with siting and noise; for example one traditional remedy involved locating the equipment in a large underground chamber. Unfortunately none of the methods attempted proved particularly successful.

3. The Modular Solution

Throughout the 1970's, the small group of people within ERS evaluating governor equipment were also aware of the complaints and comments from Regional engineers. It was apparent from the wide variety of equipment available and the lack of a standard design that almost no two governor stations were the same.

In summary then, there appeared to be an outstanding need for a governor module with the following features:

(a) As remote as possible from the general public.
(b) Reliable, simple and standardised.
(c) Capable of being maintained in a workshop rather than on site.
(d) To facilitate (c) above constructed on a modular basis.

Ron Aynsley and Dave Innes lowering the Governor Module into the underground chamber.

Arising from these considerations, an idea from Arthur Smelt was taken up, early in 1978, by Derek Stoves and Roger Hawkins, leading them to propose a radical new standard design. Its potential was recognised by Dave Needham and a working model, consisting of re-packaged proprietary components and operating in the inlet pressure range of 2-7 bar, was quickly assembled to prove the concept. This model was demonstrated to the Research Committee when it visited ERS that autumn where it caught the attention of the Chairman, Sir Denis Rooke.

Events began to move quickly after that. A market survey showed that whereas the company operated about 2,000 governors in the 2-7 bar pressure range chosen to prove the concept, it operated about 20,000 at below 2 bar and our efforts were thus redirected to this area. Alan Spearman assembled a dedicated team of engineers and scientists, with design remaining the responsibility of Derek Stoves and development under the control of John Wilkinson. Design draughtsman Ernie Hatley became a key member of the team, later to earn the distinction of being the longest serving member from his designs for the proof-of-concept unit in February 1978 up to his retirement in May 1992.

The design, which emerged from several conceptual sketches together with an analysis of the failures of conventional governors, contained a single regulator valve and a fast acting safety shut-off valve. All the working parts were contained in an easily removed cartridge which, together with a filter, were housed in a ductile iron body built into the distribution main itself. Furthermore, in order to meet the difficulties of siting and noise, the new design had the working components located below ground but accessible to personnel working from an above-ground position.

The key element in the design of the pressure control unit is the stack of four identical diaphragms with the underside of each diaphragm connected to outlet pressure and the upper side connected to atmosphere. Increased pressure moves the diaphragm stack up, causing the control valve to close and restore the outlet pressure to its preset value. The cartridge also includes a slamshut valve which closes very rapidly if the outlet pressure exceeds a preset safety limit, a pressure relief valve and a device which can be operated by a timeswitch to increase the pressure at times of high demand to compensate for the increased pressure drops in the distribution system that occur in such circumstances. The only part of the system which is above ground is a small combined vent stack and instrument housing which contains equipment for monitoring performance and the timeswitch controller.

The filter and cartridge are exchanged through a standard 600 mm diameter manhole cover set into the ground. The cartridge has been designed for a long maintenance free life and for overhaul in a central workshop, thus eliminating on-site maintenance.

The vent stack can be up to 15 metres away from the pressure control unit and is connected to it by flexible pipes. All connections to the cartridge are made automatically as it is inserted in the body.

Following the construction of a number of prototype units, the module underwent extensive laboratory tests and field trials. Laboratory testing included examinations of the effects of dust storms, gas conditioning agents, corrosion, and the consequences of ignition of gas leaking from fittings in the cartridge and instrument housing. An environmental chamber was used for operational tests from -20°C to 50°C at up to 100% relative humidity. In addition to the main test rigs, numerous smaller rigs were constructed to investigate specific mechanical problems such as spring friction and hysteresis, and to evaluate designs and materials for seals and diaphragms.

The first field trial was conducted by Dave Murphy, assisted by Noel Palmer and 'Red' Skelton, at Blackpool in October 1980. Within the next five years the trials programme had extended to cover all Regions, with over 50 modules subjected to a wide range of environmental and operating conditions. As confidence grew, many of the later trial units were acting as fully operational governors in below ground installations.

Although the development was conceived at ERS, Mr James McHugh, the then Member for Production and Supply, was the driving force for its implementation throughout the Company. He set up and chaired a review panel to monitor and guide progress. This panel had members from Regions and HQ representing Engineering, Purchasing, Finance, Personnel and R&D functions.

As the field trials progressed and generated confidence in the equipment, the panel concentrated on how and where it should be manufactured. The options which were considered included setting up a manufacturing unit at ERS, using an established governor manufacturer and forming a new joint venture company. The latter route was eventually chosen and a company called British Synergy Ltd was set up in 1984 as a joint venture between British Gas and the engineering group UEI plc, with a contract to supply 2,450 modules over a five year period.

ERS was heavily involved with British Synergy throughout the contract, with Dave Bell working full time as Liaison Engineer and the first British Synergy recruits were trained at ERS by Les Behenna. Every cartridge produced by British Synergy in the first three years of the contract was shipped to Low Thornley for a full flow gas test, necessitating a special test set-up, designed by Mick Robson, with the testing co-ordinated by Dave Marshall.

In 1982 John Wilkinson took up a secondment in London, whereupon Derek Stoves took responsibility for development as well as design. Ken Wood replaced Derek as Project Leader in 1984.

4. Later Developments

One of the early decisions of the review panel was that one size of module, in terms of flow capacity, outlet pressure range and clock controlled outlet pressure change, would satisfy the vast majority of potential installations. This decision was soon overtaken due, amongst other reasons, to changes in operating practice and technology available to the Regions.

After the design had been fixed for production it became clear that there were many potential sites which required a module of twice the standard flow capacity. These sites were generally in large cities where the difficulties of installing a conventional governor were most acute. ERS set about to design a new cartridge which would be interchangeable with the version just about to enter production and would use the same components except for larger regulator and slamshut valves. Much development work from Mick Lanty and Ken Watson went into maximising the capacity whilst retaining the stable control of the lower capacity cartridge at small gas throughputs. This enabled the new cartridge to be produced as a direct replacement for the original in order to minimise the production and stockholding costs associated with the manufacture of two models at the same time.

The new cartridge, universally known as the 'HiCap', began production in 1987 after 800 of the original version had been delivered. The final capacity was $2^1/_2$ times that of the original cartridge.

a) During the late 1980's, developments in narrow trenching and trenchless pipelaying had made it economically viable to supply gas to small isolated areas which had previously not been supplied. Small diameter PE mains were extensively used to reduce construction costs but resulted in greater than normal pressure drops. Consequently higher governor outlet pressures than could be provided by the module were required. ERS designed a modification to the cartridge which doubled the available outlet pressure.

b) Secondly,the advent of electronic closed loop pressure control to maintain the extremities of a district at constant pressure irrespective of gas demand created the opportunity for an electronically controlled module. ERS responded by designing a modification to make the module compatible with electronic control equipment for conventional governors.

c) In a number of districts the pressure difference between periods of high and low demand was greater than the 10 mbar available. Responding to requests from these potential users, ERS designed a special version having a maximum pressure step of 20 mbar.

Much of the credit for the development of these variants is due to Brian Dixon and Mick Lanty. The three types of conversion required extensive workshop facilities and were expensive to carry out. ERS technicians, mainly Ron Aynsley, Bob White and George Foster, initially converted modules on behalf of Regions but later a conversion centre was established in British Gas North Western to serve all Regions.

5. The Export Module

Although Regional users were generally enthusiastic about the module, unfavourable comments were received in three areas. Firstly, they wanted to overhaul cartridges themselves rather than have to return them to the manufacturer; secondly, the cost of producing the special versions referred to above was too high; and thirdly, the equipment cost about twice that of conventional governors, making its use difficult to justify at sites where mains diversion, land purchase and governor house construction were not significant factors. Furthermore, Global Gas held the opinion that the price was a major barrier to overseas sales.

In late 1989 Ernie Shannon, then HQ Director of Engineering Research, gave Ken Wood, Dave Bell and Ernie Hatley almost a free hand in redesigning the module to address these points. Three schemes were prepared and costed. The lowest cost option, named the 'Export Module', was progressed through detailed design and prototyping with support from Gas Business and Global Gas.

The new version has been designed with fewer parts, many proprietary components have been introduced and the remaining components have been simplified by, for example, using reinforced plastic mouldings in place of aluminium castings to eliminate the cost of machining.

The number of main diaphragms has been reduced from four to one, with compensation for the smaller total diaphragm area provided by an amplified control pressure supplied through mass produced, low cost proprietary products.

Maintenance costs have been reduced because of the low spares prices for the proprietary components and the simplified construction which will enable maintenance in the purchaser's own workshops. Simple modifications may be carried out by the purchaser to provide the conversions referred to previously.

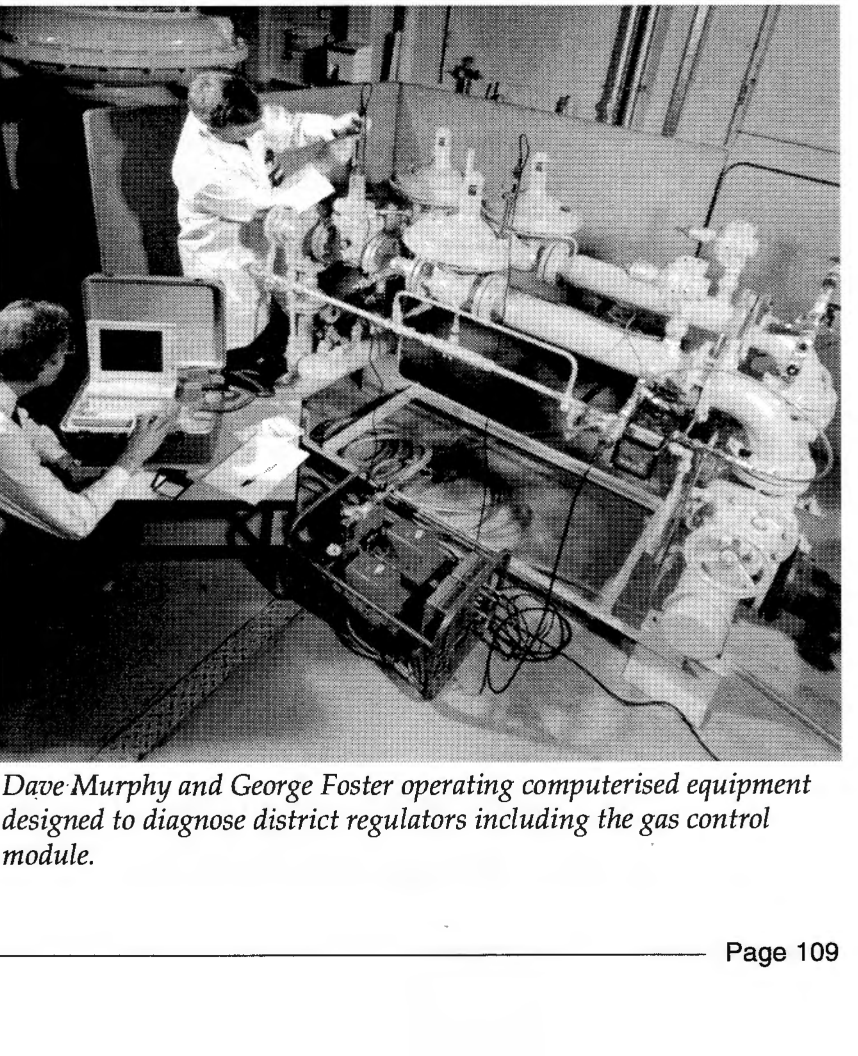
A pre-production batch of 25 modules has been manufactured by Bryan Donkin Ltd, a long established supplier of conventional governors. These units are currently undergoing extensive laboratory and field testing with encouraging results, and it is anticipated that the design will enter full scale production early in 1994.

6. Concluding Remarks

British Synergy was wound up on delivery of the final unit in July 1991. Pending the introduction of the Export Module, HiCap Modules are now supplied directly to British Gas by Yewlands Engineering Ltd, who were part of UEI (now Carlton Communications plc) and were British Synergy's main sub-contractor.

The module has been a success without question. Almost 3,000 units have been installed in the eight years since the first was delivered in 1985 and the continuation of the principle is assured by the development of the 'Export' version.

A rough count has shown that about 85 members of ERS staff have been involved with the project at various times since its inception whereas just over twenty have been mentioned by name in this short account. Only lack of space has prevented the others from being mentioned. Some of those named may feel that they made a larger or a more important contribution than that described; this is simply a feature of the way the written story has developed.



Dave Murphy and George Foster operating computerised equipment designed to diagnose district regulators including the gas control module.

LOW PRESSURE PIPE INSPECTION (DIMP)

by Roger Ashworth

1. Introduction

In 1993 the British Gas Distribution system is comprised of around 420,000 km of pipe operating at low and medium pressures (0.02 to 2bar). Around 60% is cast iron, around 35% is polyethylene and the remainder is steel. While the Company has a policy of replacing cast iron with polyethylene, at current rates of replacement, cast iron will still be around in 50 years time. Consideration will, therefore, need to be given for many years to come to the condition of those parts of the system containing cast iron pipes.

The condition of the ageing cast iron is of concern because of the possibility of corrosion and fracture leading to incidents. Since 1973, the company has pursued active policies to replace those pipes which, given failure, would have the worst consequences. National replacement policies initially targetted low and medium pressure small diameter mains, with pipes being earmarked using a national 'points scheme' based mainly upon location and hazard, rather than on some objective measure of pipe condition. Recently, with the more obvious candidates for replacement dealt with, there is a need for a cost effective replacement strategy based upon condition.

For a proper assessment of the condition of buried cast iron pipes, assessment of the pipe bed, as well as the pipewall is needed because fractures occur due to stresses caused by ground movement. For these buried pipes, internal inspection (and repair!) methods have long been recognised as offering cost effectiveness, avoiding the need for much excavation reinstatement.

2. Initial Feasibility Studies

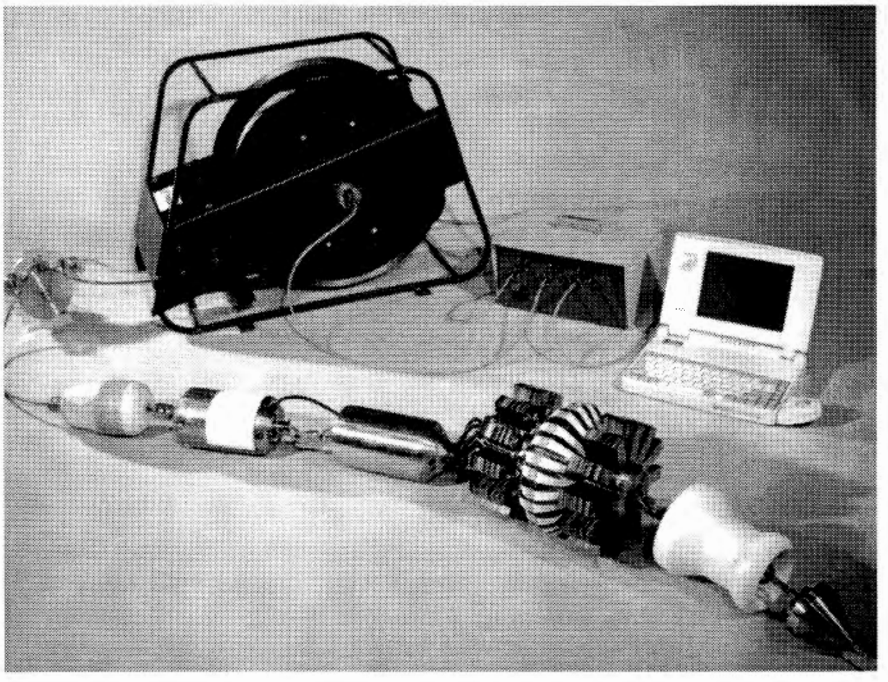
Credit for the maintenance of momentum on distribution mains condition assessment at ERS is, for the most part, Les Hinsley's. As Division Manager of Distribution Engineering Division in the early eighties he marshalled the resources of Malcolm Howe and Ian Glasgow who reviewed the main contenders for wall inspection of cast iron pipes, ie ultrasonic, eddy current and flux leakage techniques. In the same period, bed inspection using gamma ray and neutron backscatter techniques were investigated by Dave Pinchbeck, Dave Nelson and Ian Mearns. The use of acoustic and thermal methods was also considered. (Nuclear and mechanical impedance techniques for bed inspection are still being pursued today, by Peter Nolan and Roger Ashworth respectively.)

3. The 'Concept' Tool

In 1986 collaboration with development staff at OLIC began on a low cost/ low resolution pipewall inspection system. This resulted in a 'Concept' proving 6" flux leakage tool being trialled by ERS in local abandoned mains in 1987. Les Hinsley, Bill Drew, Malcolm Wayman, Roy Chipchase and Ian Mearns at ERS, in conjunction with Joe Bell, John Burd, Paul Robson and Don Anderson at OLIC, formed the backbone of the early development team.

Being a winched system, with an umbilical link for power, remote data collection and analysis, the project raised many new development opportunities in on-line inspection technology. Although anticipated inspection speeds were an order of magnitude slower than those for high pressure transmission pipes(metres / minute rather than metres / second), the environment in distribution pipes, and the quality of the material to be inspected, was far worse than the steel pipe of the transmission system.

From the outset, electromagnets were used in place of the more conventional permanent magnet designs, and Hall effect sensors collected the defect signals. The data handling system was designed around cheap, readily available and ever more powerful personal computers (PC's). The smallest transmission inspection pig in service at the time was 12 inch, although 8 and 10 inch systems were on the drawing board at OLIC. Because of the severe space restrictions Joe Bell took the bold and imaginative step of using foils rather than the normal bristle tufts for the suspension and magnetic circuit completion. These allowed easy prototype changes, and resulted in a much shorter pig for the same magnetic performance. This was of fundamental importance for the later successes of the system.



The Magnetic Pig – used for inspection of distribution pipelines – DIMP.

The initial 'Concept' flux leakage tool had limited range and could only tackle straight runs. However it did demonstrate the viability of inspection of cast iron pipes, despite the variations of the material's magnetic properties.

During 1988 the main thrust of the project was re-directed towards the inspection of larger diameter mains, as inspection costs have to be considerably less than replacement costs, and the larger diameters have a relatively high replacement cost. Subsequently, considerable effort went into the development of so called 'flux pads', miniature pig sub-assemblies, which could be dropped in through a top opening no larger than a third of the diameter of a 24" main, and then expanded internally to give full circumferential coverage.

'Concept' prototype pads were built and tested by Jim Ramshaw, who still is responsible for most of the physics test work for the whole project, and work was progressing towards engineering a prototype system. However, many engineering challenges were recognised to be ahead, not least being bend and fitting negotiation combined with the high drags to be expected in these sizes (of the order of 1 tonne). However, Les Hinsley, now project manager in the restructured ERS, still doggedly pursued Regional field trials of the 6 inch 'Concept' system.

4. From 'Concept' to Field Usable System

In May 1990 a development trial took place in 6" ductile iron in British Gas South Eastern, which again demonstrated the potential of the system, but the need for more robust sensor and umbilical systems became very apparent. The 'Concept' system had never been intended for field use!

Meanwhile, laboratory work had made significant progress both in robust bi-directional sensor sledge developments, resulting in a patent application by Ken Watson, and in the ability to pass the tightest elbows. Here a novel towing swivel, subject of another patent application by Dave Smart, was perfected which facilitated elbow negotiation with minimal drag change. Prior to this such bend negotiation had been thought to be impossible for such a pig.

Work had also progressed on the data analysis side. Tom Gilmour was developing and incorporating defect sizing algorithms which would eventually provide on-site analysis and presentation of pipe condition within ten minutes of the inspection, all with just a PC.

5. The Development of DIMP (Ductile Iron Magnetic Pig)

An incident at Warrington in November 1988, caused by the corrosion of relatively recent (post 1960s) ductile iron pipe had alerted North Western region to the need for inspection. Their condition surveying was initially done by trial hole and visual inspection, and the results of this had indicated the need for better and cheaper assessment. In October 1990 Les Hinsley and Brian Barber of North Western produced the case for 6, 8 and 12 inch DIMP systems to provide data on British Gas's ductile iron population.

The design/development teams, now headed by Peter Couchman (Mechanical), Joe Hopkins (Electronics), John Burd (Physics) and Tom Gilmour(Data processing) set about the task of translating the 'Concept' tool into an operational system. A broad requirement specification of 400 metre range, with at least two 1D bend passing capability in that length was set. On-site defect sizing was to be better than +- 20% of wall thickness on defects larger than 10 mm. The first 6" system was scheduled to be available by February 1991. The first of many trials with the first system took place in Rochdale in June 1991.

Designs for a second generation DIMP, incorporating all the lessons learnt from the first, are now underway to provide the means for a national survey of ductile iron pipe scheduled for 1993, sought by HQ Regional Services Engineering.

6. Selling DIMP technology

The opportunities for exploitation of the system in steel refinery pipework was demonstrated in an ERS trial for BP's Llandarcy Oil refinery in July 1991, organised through Global Gas and OLIC. Additionally, in May 1992 the "WIMP" a 70 bar operating pressure, environmentally sealed version of DIMP, successfully performed its first trial for Southern Water, surveying a pipe prior to concrete lining rehabilitation. Most recently, in 1993 Partington Engineering Services have completed the first commercial contract using WIMP to inspect 6km of 6inch steel pipe cladding for a high voltage cable, again as part of a rehabilitation exercise.

7. A Glimpse into the Future . . . ?

In the case of DIMP, it can be argued that ERS has fulfilled its role. The technology has been successfully developed and it is now time for the exploitatlon and marketing wings of the organisation to reap the dividends. However, support for the existing technology will be required for as long as it used, and refinement and development should go hand in hand with this process. Developments of the sensor system are already in hand, and alternative sensing technologies which offer operational advantages, especially in larger diameter mains, need to be developed.

In the short term there is the obvious need to inspect live mains. This brings with it anticipated technical problems of threading and cleaning the main, and reliability. Initially convincing prospective users of reliability, and delivering it, will be a major hurdle. The first live regional trial is scheduled to take place in North Thames in 1993.

A logical progression in the longer term is towards an integrated suite of tools for live maintenance of the system. This will include bed inspection, or stress measuring systems, leakage location and measurement systems and internal (joint) repair systems. Some of these are already under development and at concept proving stage at ERS.

In the really long term we can look forward to developing similar, but different technologies to validate the PE system, when it approaches the end of its 50 year design life.

A continuation of the established tradition of integrating our existing expertise with the latest developments from outside, constantly trying out different approaches and striving to add value to the product, and not resting on our laurels will ensure a healthy and prosperous future.

FRACTURE PROPAGATION

by Geoff Fearnehough

1. Introduction

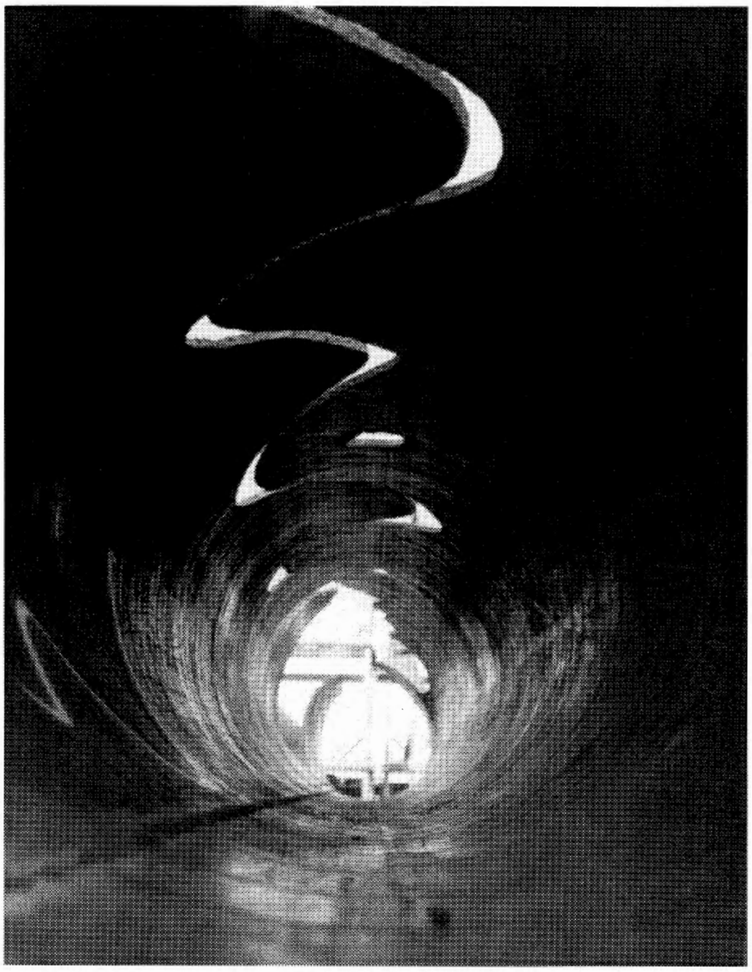
In contrast to most other pipelines, if a gas transmission pipeline is ruptured, extensive propagation of cracks can occur. This is because the pressurised gas acts as a store of compressed energy which can continue to drive a crack along a pipeline virtually indefinitely. Major long cracks have occurred in the United States following rupture of pipelines from defects or mechanical interference by digging equipment. For example, an 8 mile-long failure occurred there in 1959. Clearly, this type of behaviour is generally unacceptable because the hazard is potentially spread over a long distance and because of the time and expense of pipe replacement. The pursuit of a solution to this problem has occupied gas companies and pipe manufacturers for over two decades. Essentially, the problem can be avoided by either operating at low hoop (circumferential) stress levels - by reducing pressure - or by specifying a pipeline steel with an adequate level of fracture toughness. The specification of correct levels of stress or toughness has been the goal of the extensive theoretical and experimental studies at ERS almost from the very outset.

2. Brittle Fracture

The original manifestation of the fracture problem was due to brittle fracture. Essentially, a brittle fracture involves complete fracture through the pipe wall with little deformation of the steel and, hence, requires relatively little energy to maintain crack propagation. It occurs suddenly and the fracture can travel at speeds of about 500 metres per second. Brittle fractures occur at low temperatures since structural steels have a fracture transition temperature below which fracture occurs in the brittle mode and above which fracture is in a ductile mode. The transition temperature depends on the microscopic grain size of the steel, the smaller the grain size the lower the transition temperature. Thus, the larger the size of the grains the more prone to brittle fracture is the steel. Unfortunately, most steelmaking practice in the US and in the UK before the 1960's produced steels with large grains and the pipes were therefore at risk of extensive crack propagation.

One of the earliest investigations carried out by the Engineering Research Station was a full scale test on a pipeline on the Yorkshire/Derbyshire border. Concern had been expressed that, because the early supplies of steel were of a potentially brittle character, the pipe might suffer from extensive fracture propagation during pre-service hydrostatic testing. Hydrostatic testing involves pressurising the pipeline to high pressures in order to cause failure of any potentially serious defect before the pipeline enters service; in contrast to current linepipe production the early pipe supplies were prone to failure from such defects during hydrostatic testing. The full scale test had to be carried out on cold pipe and large quantities of ice blocks were ferried from the fish market in Manchester! The required temperature was reached in the middle of the night, when the first explosive charge was fired on the pipe to initiate a crack. However, only a small, non-propagating, crack resulted indicating that there was not a problem, a conclusion which had been predicted by ERS because water is not compressible and therefore contains insufficient stored energy to allow crack propagation.

The development of specifications to prevent fracture propagation in service made extensive use of the results of a project, sponsored by the American Gas Association (AGA), at the Battelle Memorial Institute, which had culminated in the development of the Battelle Drop Weight Tear Test (BDWTT), a test specifically designed to evaluate



A long running brittle fracture in a steel transmission line pipe, following a full scale test at Otterburn.

whether the steel is brittle or ductile. However, the linepipe specification most commonly used in 1967, the American Petroleum Institute specification API 5LX, was deficient in that it did not include provision to protect against brittle fracture propagation. Consequently, a supplementary British Gas specification, GC/PS/LXI, was issued by ERS to cover this deficiency. Much of the background to the fracture problem was obtained in 1967 in a four-week tour of North American gas transmission companies, linepipe manufacturers and research institutes by Cedric Brown (then at East Midlands Region), Les Mercer, Bob Weiner and Geoff Fearnehough.

Early work at ERS was devised by Geoff Fearnehough, and concentrated on proving the necessity for, and the requirements of a toughness specification. This work included a vivid demonstration of the potential dangers of brittle fracture by means of a full-scale test at the Otterburn test site. This test resolved a dispute, once and for all, between ERS, who insisted that a toughness provision was necessary, and British Steel, who, argued that the provision was not necessary. The full scale test on a section made up of seven lengths of pipe manufactured by British Steel, demonstrated that propagation was indeed possible and that rigorous toughness standards were, in fact, required. As a consequence, British Gas applied the Drop Weight Tear Test as a requirement to demonstrate fracture toughness in new linepipe supplies. The implication of this was that linepipe of adequate fracture resistance could initially only be obtained from the continent of Europe and Japan, where the production route ensured good toughness. UK sources only became suitable after changes in steel manufacture, to produce fine grained steel, were implemented.

Having established that fracture toughness requirements were necessary for new pipe, the question was raised concerning pipelines which had already been constructed of material, which might not be brittle fracture resistant. Theoretical arguments were proposed by ERS to show that propagation would not be possible if the stress levels were limited. Battelle, in the US, did not agree with this view, claiming that propagation was not strongly influenced by applied stress level, and therefore ERS commissioned two full scale tests in the United States to settle the argument. The result proved that ERS were correct so that existing pipelines did not have to be replaced but could be downrated to a pressure at which brittle fracture propagation could not be sustained. This finding was incorporated into the Institution of Gas Engineers Recommendations IGE/TD/1.

This early ERS work on fracture was highly regarded by the American Gas Association and resulted in an informal research information exchange agreement without the need for British Gas to pay the usual high joining and annual membership fees to the AGA. This arrangement has been continued ever since.

3. Ductile Fracture

Two unfortunate consequences arose from the early introduction of 'tough' steels. Firstly, the high sulphur levels in the new steels resulted in a large number of elongated non-metallic inclusions in the pipe plate. During longitudinal seam welding those inclusions adjacent to the weld suffered delamination, and these defects then extended to the edge of the weld during cold expansion of the pipe. A number of seam weld failures occurred during subsequent hydrostatic testing of the pipeline as a result of these defects. Secondly, although the steel was fine grained and therefore not brittle, the steel had low levels of 'ductile' or 'shear' fracture resistance This was again caused by the quantity and nature of sulphide inclusions which occurred in the steel when the fine grained steel production route was initially introduced. ERS contributed significantly to the effects of inclusions on fracture resistance, particularly in investigations by Peter Rogerson and Brian Jones. The result of this low shear fracture resistance was that long propagating fractures in the shear fracture mode were also theoretically possible. At the time when ERS was proposing this possibility, two such fractures several hundred feet long occurred in North America. Consequently, a series of full-scale propagation tests were conducted at Otterburn covering all the major pipeline geometries and operating stress levels of interest to British Gas to determine the toughness necessary to prevent such fractures. This led to the introduction of toughness specifications for linepipe in 1972 based on the Charpy impact test. This test involves measurement of the energy required to fracture a small notched steel specimen. Again, the new toughness requirements resulted in a change of steel making practice. This generally involved making additions to the molten steel both to reduce the sulphur content and to modify the sulphide inclusion shape in order to achieve the required toughness levels.

The full-scale test work in facilities established by Dennis Jude and Brian Flood, and the international recognition of the ERS studies led to an International Symposium on Fracture Propagation in Pipelines, organised at ERS in 1974 and attended by over 100 representatives from European and North American companies. Significant contributions were made in papers by Allan Poynton, Geoff Fearnehough and by Ernie Shannon who conducted work, sponsored by ERS, with Professor Alan Wells at Queens University, Belfast on the analytical and theoretical prediction of shear fracture propagation.

Significant papers on shear fracture propagation were presented by Geoff Fearnehough, Allan Poynton, Ernie Shannon and David Jones at international conferences at Lehigh University in the USA and in Rome and Amsterdam. In addition, close contact was maintained with relevant theoretical work sponsored by Heriot-Watt University, Edinburgh and also at Cambridge University.

The ERS work also led to an approach by a group of European companies to carry out full-scale shear fracture tests on their behalf. As a result of these discussions, the European Pipeline Research Group (EPRG) was established in 1972. This group, the first collaborative group of its kind in Europe, arranged to fund research from members' contributions and from contributions by the European Coal and Steel Community. The EPRG has sponsored propagation tests on pipes from 36 to 48 inch diameter at both Otterburn and later, Spadeadam, resulting in the establishment of European toughness standards.

The EPRG subsequently sponsored work at ERS on girth weld defect standards, penetration resistance of pipes and the strength of damaged pipelines.

4. Underwater Fracture Propagation

The need to study fracture propagation in underwater pipelines was recognised in a paper by Geoff Fernehough published in 1976 at a conference in Amsterdam. This was followed by a test at Spadeadam in shallow water and, in 1987, by a complete simulation of a pipeline burst in deep water off the west coast of Scotland. This latter test was carried out in conjunction with a group of sponsors and was the first test of its kind. It was engineered by Dennis Jude and was extremely complicated, involving the pressurisation of a pipeline test length with a specially-controlled gas composition to simulate North Sea gas. The pipe section, 80 meters long, 900 mm diameter, was fabricated on the Clyde and towed by barge to the test site location in Loch Fyne. The floatation tanks were then flooded and the test section lowered to the sea bed. Particular care had to be taken, not only of the integrity of the component parts of the test equipment, but also of the potential safety problems to local shipping arising from the burst. The test was complemented by analytical studies by Geoff Fearnehough and David Jones on the interaction of shock waves in the water and the fracture. The test, which demonstrated that fracture propagation does not occur in submarine pipelines, also allayed fears in respect of safety because the burst resulted in a relatively minor, and local wave.

DEVELOPMENT OF WELDING/JOINING TECHNOLOGY AT ERS

by Kevin Prosser

1. Introduction

Conversion of the UK to natural gas in the late 60s resulted in the need to construct a national gas transmission pipeline system. Since there was already considerable experience of large diameter cross country steel pipeline construction in the USA, it was natural for British Gas to use materials and welding standards based on the existing American Petroleum Institute specifications. However, as a result of our different linepipe steels and construction practices, a large number of problems were encountered, particularly defects associated with welding, and it soon became apparent that British Gas needed its own expertise to solve them.

2. Early Girth Welding Problems

A team of welding and non-destructive testing specialists was established at ERS, consisting initially of Brian Horsfield, Neville Evans, Tony Doherty and Russ Lumb. One of their first tasks was to find a solution to the large number of girth weld hydrogen cracks which were being found when constructing pipelines. These cracks formed during, or shortly after, welding and were found adjacent to the weld in the heat affected zone of the pipe, Fig.X. They were due to the relatively high carbon content necessary in the linepipe steels available at that time to achieve the specified strength level. A number of steps to overcome the problem were taken, one of which was the introduction of a low yield strength root bead welding electrode to accommodate the stresses imposed on the partially completed weld during construction. A second safeguard was the introduction of full scale linepipe and fittings weldability tests into new British Gas supply specifications. These simple measures have served British Gas well and have frequently been adopted by other pipeline utilities worldwide. Finally, a British Gas pipeline welding standard, BGC/PS/P2, was written which, although based on the widely used API 1104, included a number of important additional requirements. Principal amongst these was to make 100% X - radiographic inspection a mandatory requirement; again this has now become standard practice for most European pipeline operators.

3. British Gas Approval Scheme

It soon became apparent that there was no suitable qualification scheme for the inspectors who were to enforce these new British Gas pipeline welding and non-destructive testing standards. For this reason, in 1968, the ERS Inspector Approval Scheme was introduced, initially to cover pipeline construction activities, but soon to include pipemill inspection during pipe manufacture. This latter move was necessary as a number of failures during the pipeline pre-commissioning hydrotest were associated with poor quality control at the pipemill, particularly with respect to the pipe longitudinal seam weld.

The approvals scheme was administered at ERS by Ron Chrisp, with guidance from a committee drawn from the Regions, Quality Assurance Department, Pipelines Department, and ERS. Inspectors were assessed by a combination of written examination, practical tests and an interview. Ron, and the Pipelines Department staff, carried out random site checks to ensure standards were being maintained in the field. A number of grades of inspector were approved, including Senior Inspector (Welding), Senior Inspector (NDT), Coating and Wrapping Inspector, Pipe Mill Supervisor, etc.

Since the establishment of the Approval Scheme, over 11,500 inspectors have been examined at ERS, often for more than one grade. When the Approval Scheme was initiated, it was thought that it would have fulfilled its purpose once a sufficient pool of inspectors had been approved for use on British Gas projects. However, after 25 years there is still a continuing demand for assessment, many individuals from the UK and overseas paying their own fees to gain approval. Indeed, over its years of operation the scheme has generated a revenue in excess of £2.5M for British Gas. Such is the esteem with which the scheme is held, that examinations have been carried out in Iran, Kuwait, Saudi Arabia, India, Abu Dhabi and Ireland, via the British Gas International Consultancy Service. Many of these inspectors may never work on a British Gas project, but the absence of suitable alternatives means that the British Gas scheme has been adopted as the international standard. Therefore, not only has the scheme contributed to the excellent safety record of British Gas Pipelines, but also to that of many pipelines around the world.

With the retirement of Ron Chrisp in June 1989, management of the scheme was taken over by British Gas Technical Services (Construction) Dept., and is administered from the Pipeline Maintenance Centre, Ambergate, under the direction of ERS 'old boys' Brian Cassie and Tom Avery. It is now officially known as the British Gas Approval Scheme, although old habits die hard and many inspectors still talk of gaining their 'ERS ticket'.

4. Pipeline Repair Procedures

Construction of new pipelines to satisfactory standards was only part of the problem, as there was a need to adapt and maintain, not only the emerging pipeline system, but also high pressure storage facilities. It was soon realised that existing guidelines on the modification and repair of in-service pipelines were inadequate. Neville Evans and Brian Cassie, and in the later years Ian Palfreyman, carried out a programme of 'hot tap' welding trials designed to address this problem. Their approach was an empirical one, welding trials being carried out on pressurised pipe under carefully controlled conditions, using the test cell facilities at ERS and the gas flow loops at Low Thornley. A major result of this work was the British Gas hot tap welding standard, BGC/PS/P9, first published in the mid 1970s and one of the first comprehensive, practical guidance documents covering such operations. The success of this work can be judged by the fact that the document is still in use today, largely unchanged, and the fundamental guidelines have once again been adopted by other pipeline operators worldwide.

5. Automatic Welding

In the early 1970s, the main feeder pipelines of the National Transmission System, from the terminals in the North of Scotland to the centres of population in the Midlands and South of England, were being increased in number. These large diameter, long distance, pipelines lent themselves to the first use in the UK of the rapid new mechanised pipeline welding equipment. This so-called 'automatic' welding also had the attraction of requiring fewer of the skilled pipeline welders, who were in short supply. ERS was involved in evaluating welds produced by these processes in order to qualify suitable welding procedures. Brian Phelps, Neville Evans and Bob Schofield, were all involved in helping to ensure the success of this new technology. Close links were established between British Gas Pipelines Department, ERS and CRC-Crose (now CRC Evans), one of the earliest and most successful mechanised welding companies, and these links continue to this day.

Pressure from the manual stovepipe welders trade union has restricted the use of mechanised pipe welding for onshore construction in recent years. However, British Gas has been able to utilise the technology offshore. All of the large diameter offshore pipelines constructed by British Gas have used mechanised rather than manual welding. The economic advantages of using these high speed systems are considerable, but are dependent on maintaining a low weld repair rate. Unfortunately, all current systems are prone to occasional lack of fusion defects. The repair of such defects offshore has a major impact on laybarge utilisation, and ERS were involved at an early stage in developing fitness-for-purpose acceptance standards which would minimise repair rates whilst maintaining safety and weld integrity. In the early 1980s Phil Hopkins established the toughness requirements which would allow acceptance of limited defects and Kevin Prosser and Peter Boothby investigated the factors affecting the toughness of mechanised pipeline girth welds. Welding consumables were chosen to meet the required toughness levels and these allowed the use of fitness-for-purpose standards when appropriate. ERS has also been involved directly in the approval of new mechanised welding equipment, such as the McDermott system which was evaluated at ERS prior to use in Morecambe Bay in 1982.

6. Offshore Structures

The developing emphasis on offshore related work at ERS was given further impetus in 1981 by the weld cracking problems which occurred during fabrication of Conoco's Hutton tension leg platform. ERS became involved in an investigation of the weldability of new and traditional offshore structural steels. Using a laboratory weld cracking test, the Controlled Thermal Severity test, Peter Boothby was able to demonstrate that modern steels did not follow the predictions of existing weldability guidance documents. As a result of this understanding, British Gas has been able to tailor its own offshore structural steel supply specifications to avoid potential fabrication cracking problems. The offshore weldability theme continued when David Batte and Peter Rodgerson joined Phil Kirkwood and Peter Boothby in the production of a series of papers which reviewed current understanding of the cracking and heat affected zone toughness of offshore steels and proposed a model for prediction of behaviour. This model has since been adopted internationally as a basis for understanding the welding behaviour of offshore structural steels.

Collaboration with CRC-Evans continued in 1987 when, as part of an international group sponsored project, ERS were asked to evaluate mechanised welding systems for duplex stainless steel and Incoloy 825 clad carbon steel. This project aimed to develop more efficient welding techniques for the emerging corrosion resistant alloy pipe materials, intended for offshore service in corrosive and sour fields. The programme was the start of an increasing ERS interest in the weldability of corrosion resistant alloys. The most recent example of work in this area has been an investigation of the weldability and corrosion resistance of alloys for process pipework on offshore platforms by Kevin Prosser, Arthur Brown and Mike Dale. British Gas is currently using the 'super-duplex' and 'super-austenitic' stainless steels, which were recommended as an outcome of the ERS investigation, to replace corroded carbon steel and austenitic stainless steel pipework on the Rough and Morecambe platforms.

7. The Future

Traditional welding processes applied to carbon and alloy steels, continue to play an important part in the research programmes being carried out by ERS. However, the ongoing development of materials, and the need to minimise the costs of using expensive alloys, whilst maintaining satisfactory performance in an aggressive environment, has led to interest in other branches of materials and joining technology. Two examples illustrate the expanding contribution of these new areas to the ERS work programme. In the first, hard surface coating techniques and consumables have been evaluated, in order to combat the scoring damage which has been experienced by large diameter ball valves on the Rough facilities and platforms. As a result of testing at ERS, optimum surface coatings have been chosen and prototype valves have been tested in the severe service flow rig at Bishop Auckland. In the second case, adhesively jointed glass fibre reinforced pipe is being evaluated for firewater systems on offshore platforms. Again, the ERS outstations have played a vital part in this investigation, high flow rate erosion testing and water hammer testing being conducted at Blyth, and jet fire testing being conducted at Spadeadam.

These are just two examples of the new challenges facing the welding and joining technology research group at ERS. As British Gas continues to develop its interests around the world, new types of materials and new applications of existing materials will result in the need for new joining methods and will provide a plentiful supply of future problems to solve!

THE DEVELOPMENT OF TD/1

by Dennis Neale

1. Production of the Code of Practice

ERS involvement with pipelining began with welding, inspection and fracture resistance. After the 18" methane line had been built from Canvey to Leeds in 1962, to supply imported gas from Algeria to some Regions, North Sea gas was found and it became apparent that major pipelining activities would have to be carried out in a heavily populated country.

The existing pipeline code, IGE674, did not address the problems of safety, other than by making provision for basically sound engineering design and inspection during construction. It therefore rapidly became evident that IGE674, and a number of other Institution of Gas Engineers' codes of practice needed to be reviewed and committees were assembled from engineers competent in the expertise being considered. These committees bore the same name as the code they were reviewing and an IGE674A committee, later to become TD/1, was formed to produce improved recommendations. Over the years ERS was represented on this committee by a succession of people, such as John van der Post, Les Mercer, Dennis Neale, Derek James and Geoff Fearnehough.

2. Research Projects to Support the Code

Project work was set up, at ERS and MRS, to provide the basis for the committee's decisions, and this work initially examined three primary areas:

1. causes of failure,
2. consequences of failure,
3. materials and inspection.

Once these were established, work could commence on methods of reducing or controlling the hazards associated with gas transmission. The main target of the materials work was to establish suitable material and fabrication specifications for new pipelines and components, then ensure that coatings and cathodic protection methods could maintain the pipeline integrity over a long lifespan. However, as the Materials work is covered elsewhere, the remainder of the present article will only be concerned with work on the causes and consequences of failure.

A great deal of data on US pipeline failures had been collected by the American Department of Transport (DoT). These data were made available to us and formed the basis of the co-operative and fruitful relationship we have had with the DoT ever since.

3. The Causes of Failure

3.1 Corrosion

From an analysis of the DoT data it was apparent that the major causes of failure of US pipelines were mechanical interference and corrosion, followed by construction defects and other causes, such as land movement. Most US pipelines had been coated against corrosion at the construction site. The bare steel pipe was welded together alongside the trench in which it would lie, and a wrapping machine would then travel along the length of the pipeline applying a coal tar based coating. The bare pipe had minimal cleaning, so the coating bond was not adequate for full corrosion protection. It was reasoned that, since the US pipelines were old and had been wrapped with earlier, less effective coatings, our pipelines would show a lower incidence of corrosion. The materials groups at ERS ran numerous trials and made recommendations for modern, more effective coatings, culminating in the epoxy coatings now used.

Many US pipelines were unprotected by cathodic protection (CP); in many areas, e.g. deserts, this is unnecessary and ineffective. However, improved methods of applying and monitoring CP were developed and/or tested for effectiveness. It was reasoned that these improvements would reduce the incidence of corrosion to negligible levels if the system was well maintained. This left the problems of mechanical interference and construction defects as the major likely causes of pipeline failure.

3.2 Construction Defects

Construction defects, largely in the form of axial seam weld cracks, were dealt with by pre-service hydrostatic pressure testing of completed pipeline sections. In order to eliminate defects which could fail during service, the necessary test pressures were set to bring the pipe wall as close as possible to its yield stress. Procedures were developed, and backed by small and large scale tests at the remote Otterburn site, to verify the effectiveness of this method. This method has proved to be very effective at eliminating failures in service from construction defects.

During this period of intensive testing at high stress levels, a great deal of information was obtained about the growth behaviour of cracks. It was necessary to understand both the slow tearing that occurred during testing to yield, so that the condition of the cracks could be predicted after test, and the dynamic crack behaviour in the event of pipeline failure when carrying gas. Depending on the properties of the steel, from which the pipe had been made, the pipeline could either shatter over a very long length, projecting great shards of metal at high velocity (the 'brittle' mode) or could tear less rapidly, again in the axial direction (the 'ductile' mode). Research indicated the values of the steel test parameters which would eliminate the brittle mode and minimise the ductile tears to acceptable lengths in the event of pipe failure, and these parameters were put into the specifications for gas pipelines.

3.3 Mechanical Interference Damage

Work was undertaken to test the strength of pipes when attacked by various types of excavating machines. Initially it was expected that this could be done by using a drop arm carrying a standard digger tooth to simulate the action of the excavator. Using the manufacturer's data on these machines, we attempted to correlate the energy and/or momentum figures from the drop arm tests with the estimates of these quantities from the manufacturer's data. However, the results of these comparisons were unsatisfactory.

We then found that the Military Vehicle Experimental Research Establishment at Highcliffe had carried out work to establish accurate information on the behaviour of excavating machines and a visit was duly arranged. Their interest in the problem stemmed from the need to use the most efficient digging machines available, so they had carried out performance tests on a large range of machines. We arrived at the gate, and met one of our party who had been on another visit elsewhere. He arrived in his car registered in Northern Ireland, and he spoke to the guard at the gate in his normal Belfast accent. His car was immediately pounced upon and thoroughly searched, in spite of our vouching for his good character!

Using excavating machine data, the results of the drop arm tests still gave rather poor correlation, so a more extensive test programme was started. Actual excavator teeth were instrumented and used on excavators and the drop arm tests. In addition, an instrumented tooth was used on a mechanical test machine to apply load slowly to a supported pipe section. It then became possible to understand the dynamic effects of pipe and excavator and so produce slow penetration tests. When such tests were performed on pipe using hydraulic rigs, a recommendation on pipe wall thickness to protect against machines was eventually produced.

Many of the Company's existing pipelines were below the recommended thickness and alternative means of protection, such as cover plates and sleeving therefore had to be developed. In order to verify their effectiveness, these were again subjected to machine attack tests at the Otterburn test site.

Methods were developed to enable existing pipelines to be sleeved in situ, using pipes split axially into two and rewelded in the trench. This was a very expensive and difficult procedure which was demonstrated by a full scale trial at Middleton-in-Teesdale. The test was very successful in demonstrating the practicality, but also the difficulty of the work. Contractors were hired to carry out the test, under the supervision of Dennis Jude. Whether the early morning contractors' breakfast cooked over a fire on a shovel did his digestion any good he has never mentioned!

4. Patrolling

The effectiveness of helicopter and ground patrols to guard against random use of excavators was also examined and improved, because it was recognised that prevention was better than cure. Owing to the random nature of digging, it proved very difficult to give any guarantees that this procedure could be totally effective at a reasonable cost. Patrolling does however frequently detect where activity is about to start, or has finished, and hence enables good follow-up checks to be made on the pipeline using localised inspection techniques. To back it up a PR exercise, aimed at all the landowners along the pipeline, coupled with publicity to excavation machine owners and operators, maintains their awareness of the pipelines and encourages them to contact the operator of the pipeline before any excavation in the area is commenced.

5. Consequences of Failure

The major hazard from pipeline failures is from thermal radiation. MRS worked on a range of sizes of failures in small pipes, and by extrapolation it was possible to predict to full scale failures. These were correlated with the data from US experience of actual failures, and the results were used to derive acceptable population densities along the routes of large diameter pipelines. Later work on punctured, as opposed to fractured, pipes gave acceptable urban and town proximities. A great deal of testing was carried out on full scale pipe sections at Spadeadam, and is still on-going.

6. Later Developments

Although initially seen as a suitable means of protecting pipelines, sleeving was demonstrated to have limited use and caused many headaches. The interspace fills were found to be unreliable and the preferred nitrogen fill was expensive to install and maintain, in retrospect. Thick wall pipe had become available with suitable properties and this was used in preference to sleeving, as risk analysis indicated it was of similar benefit when correctly used.

In later years the science of risk analysis allowed further steady revision of TD/1. Risk analysis involves a numerical analysis of the hazard using the probability of failure relative to the locality being considered and the consequences of the type of failure expected on that locality. The product of these items produces a numerical value of hazard, and judgement has to be applied to decide on acceptable values for the hazard in each type of location. The, by then, large data base of pipeline behaviour built up by ERS, allowed risk analysis calculations to be performed, which in general demonstrated that the original code was pessimistic. This has led to relaxations in some areas, which enables the pipeline system to be operated more efficiently.

CORROSION AND CORROSION CONTROL

by Arthur Brown and David Gray

1. Introduction

The development of the transmission system involved considerations of corrosion and the necessary means of protection. This essentially depended on the application of coatings and cathodic protection to the external surfaces of the pipelines exposed to underground environments. In the early days, when reformed town gas was still being used, there was also involvement with internal coatings and with problems arising from internal stress corrosion cracking. Indeed stress corrosion cracking has been an on-going subject of interest on the eternal surfaces of pipelines over the years. The following sections describe the ERS involvement with cathodic protection and condition monitoring, coatings developments, and the stress corrosion investigations over the years.

2. Development of Coatings Technology at ERS

The formation of the Coatings Section during 1968, within the earlier established Corrosion Group at ERS, brought together the expertise of David Gray and Ron Bates and consolidated a source of vital anti-corrosion expertise. This was conceived to help protect the high investment programme of an industry in the throes of change, and to meet the challenge of transition from traditional low pressure coal gas supply, to high pressure engineering of a steel pipeline supergrid, now supplying natural gas throughout the UK.

The work which came to be dominating by the early 1970s was, undoubtedly, that on external coal tar enamel coatings. Coal tar enamels are composed of mineral fillers, pulverised coal, soft pitch and fluxing oils, the proportions of which dictate the softening point and penetration of the enamel and ultimately the coating's mechanical properties and its resistance to flow under load. During application, an inner and outer glass fibre reinforcing tissue is incorporated into the enamel to improve the coating's extensibility. By 1973, in excess of 2000km of coal tar enamel coated pipe, of this composition, had been laid by British Gas.

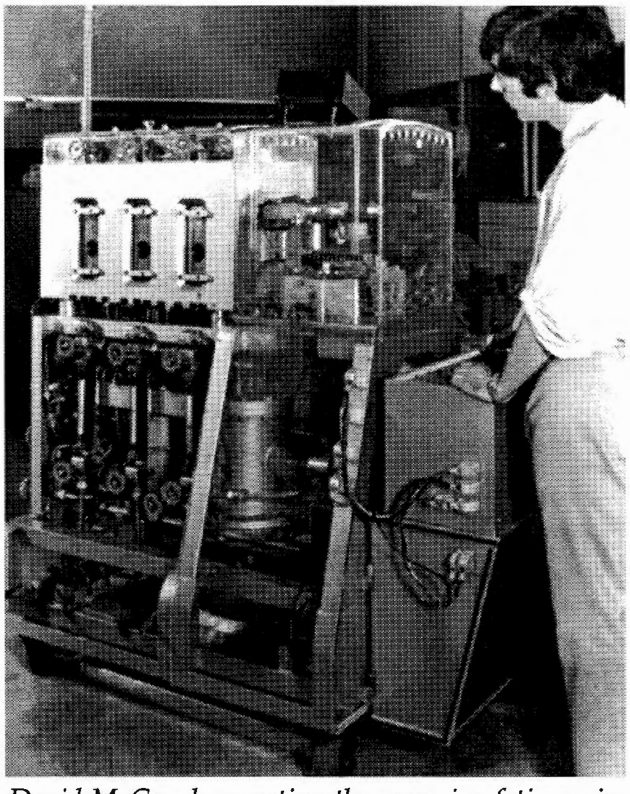
While this material had been used for many decades to give satisfactory protection to buried iron and steel pipework of various categories, operating at low pressure risk, it was quickly shown to fall technically short in many respects when the coating performance requirements were defined for the protection of large diameter buried steel pipe operating at cyclic pressures up to 70 bar and temperatures ranging from ground ambient (5°C) up to a maximum of 50°C.

The shortcomings of coal tar enamel coating manifest themselves in poor mechanical strength, extensibility and adhesion; good properties in these respects are required to resist field handling and bending of pipe and eventual hydrostatic proof testing of sections of completed pipeline. In addition to this, sections of pipeline operating in the warm zone immediately downstream of compressor stations suffer slow load penetration and soil stress effects. Disbonding of coal tar enamel coatings takes place at elevated temperature and when high cyclic stresses are applied these contribute to the development of stress corrosion cracking on pipelines. Such cracking was a significant source of pipeline fracture in the USA during the 1960s and 70s.

Work at ERS identified the outer reinforcing tissue in coal tar enamel coatings as the main culprit in some aspects of low resistance to mechanical failure. Significant improvements were shown to be possible, though at a price! These were achieved by variations in primer, polymer modification of the coal tar enamel and replacement of the fibre glass tissue by more extensible knitted glass wool and high temperature polymer reinforcements during laboratory and full scale pipe mill coating trials. Remaining problems with coal tar enamel proved difficult to resolve, suggesting the need for an alternative approach.

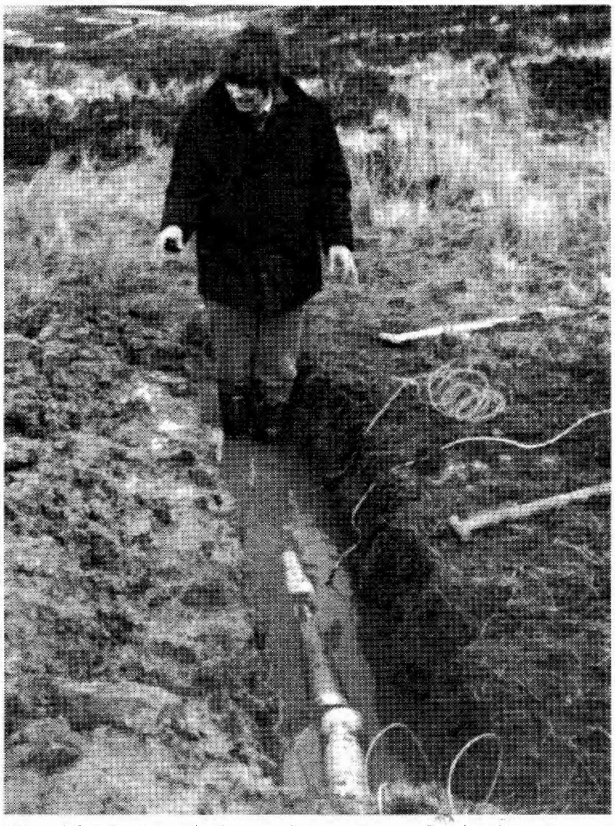
During the early to mid 1970s, emerging interest and new developments in the field of fusion bonded powder coating technology provided this new approach, and ultimately the solution. Epoxy powders are partially reacted mixtures of epoxy resins and curing agents, containing pigments, fillers and minor additives such as flow control agents and thermal stabilisers. The basic concept for application of fusion bonded epoxy as a thin film protective coating to replace coal tar enamel on pipelines, whilst essentially practical and simple in theory, was viewed initially as a somewhat radical prospective change, when the implicit 90% reduction from the typical 5mm coating thickness to 500μm was considered.

Fusion bonded epoxy powder coatings are created by electrostatic spraying of suitably formulated epoxy compositions on to pre-heated steel surface; melting and coalescence of the powder particles then occurs to form a hot liquid coating which wets, flows and bonds to the substrate, before finally cooling to produce a tough firmly adherent thermoset coating. Laboratory evaluation of the early powder formulations revealed weaknesses of low flexibility, brittleness and poor adhesion, particularly in association with applied cathodic protection. Ongoing studies during the mid 1970s backed by thermal analysis data which could be quantitatively related to coating performance, gradually and in collaboration with epoxy powder manufacturers, yielded coating materials with the desired mechanical and environmental performance properties. Transition from promising laboratory scale studies on small sections of coated pipe was effected during the late 1970s through full scale coating trials on large diameter pipe carried out in Europe and the USA, since no such facility existed in the UK.


David McGeagh operating the corrosion fatigue rig (August 1971).

Success from these trials encouraged a joint British Gas/Bredero-Price investment to build the first UK powder coating plant for large diameter pipe at Leith; ERS coating personnel were heavily engaged following this, by helping to commission the coating production line. The plant operated on a fully commercial basis as British Pipe Coaters Ltd., (BPCL), with Les Mercer as one of the Directors. By 1993 BPCL had coated a total of 300,000km of pipe (24 million pipe lengths) for oil, water and gas utilities throughout the world.

Coating of individual pipes in the mill on the line follow through batch basis is a reasonably straightforward and repeatable process, since the items to be coated are identical and simply shaped. However a pipeline grid requires not just pipe but many forged steel beds and 'T' sections of varying geometries, which do not readily succumb to production line coating. Two different coating philosophies were pursued and developed in parallel during the early 1980s toward the realisation of a fully integrated high performance pipeline coating system. The first of these, again using epoxy powder coating, but with modified formulations, allowed the powder coating to be applied electrostatically by manual spray on pre-heated fittings or by dipping pre-heated fittings into a tank of pneumatically fluidised powder. The second involved the testing and development of liquid multicomponent urethane and epoxy compositions which could be applied by spray, brush or trowel either at the coating mill or at site. The application flexibility catered for the coating of complex pipework arrays, for example at compressor stations and weld joint tie-in work. Development of both methods to produce an integrated coating system, again in common with linepipe powder development work, involved laboratory through to full scale mill pilot trials to prove the techniques.



David McGeagh (again) testing a Cathodic protection system in rather less than laboratory conditions.

The final extension to powder coating techniques was accomplished during the late 1970s/early 1980s with the successful development of field weld joint coating equipment in collaboration with specialist coating contractors. This enabled the application of completely self-integrated epoxy powder coating systems over long pipeline runs. The work culminated in the publication of a code of practice (GBE/CW5) and technical specifications (GBE/CW6 Parts 1&2). These documents were adopted by oil and gas utilities world-wide and now form the basis of European and ISO standards.

To date British Gas has installed over 2000km of fusion bonded epoxy coated pipe and over 1500 fittings involving the application of approximately 4 million kg of powder.

3. Cathodic Protection & Condition Monitoring

Cathodic Protection (CP) has long been used in conjunction with coatings to protect buried gas transmission lines against corrosion. Corrosion is an electrochemical process which can be slowed and even stopped by forcing direct current to flow through the soil to the pipe. This is achieved by either connecting to the pipe a sacrificial anode made from a more active metal such as magnesium or, in the case of impressed current systems, by connecting a transformer-rectifier between the pipe and a non-consumable anode. Sacrificial anodes are most suitable for short lengths of pipeline, whilst impressed current is generally more efficient for long, large-diameter pipelines.

Most of the transmission system has been protected by impressed current CP, but up to the 1970's sacrificial anodes were used to protect casings at sleeved crossings. A number of leaks occurred at these sites and investigative work at ERS showed that if the pipe/casing annulus contained a conductive fill, CP current from the casing anode could be picked up by the carrier pipe and discharged back to the casing, causing carrier pipe corrosion. The situation was remedied by disconnection of the casing anodes and in some cases fitting an adjustable resistor between pipe and casing to provide controlled CP to the casing from the carrier pipe CP system.

Design of CP systems has changed little since their first use on buried pipelines, with the exception that the use of high-quality polymer and epoxy coatings has led to much lower CP current demand. The major changes in CP practice during the 1980's were associated with monitoring - particularly the use of the close-interval potential survey and more accurate potential measurement techniques.

In the early years of operation of the transmission system, CP monitoring was based on monthly transformer-rectifier checks and biannual pipe to soil potential measurements at test posts; the CP systems were adjusted on the basis of the results. Since test posts are typically 2 km apart, and a single measurement of pipe to soil potential is influenced by about 20 metres of pipeline, test post monitoring alone gives data on only 1% of the pipeline. In addition, conventional measurements of pipe-soil potential are subject to significant errors due to current in the soil.

During the 1980's, because of the development of its metal-loss detection pigs, British Eas was in a unique position to assess the validity of CP monitoring procedures. Instances were found of corrosion in pipelines which apparently satisfied the conventional CP criteria. Above ground pipe to soil potential measurements using the instant-off method, which eliminates errors due to current in the soil, showed that conventional potential measurements gave optimistic values. The code of practice for CP monitoring was changed as a result to include the use of the more accurate potential measurement methods combined with periodic revalidation of the CP systems by close-interval potential surveys in which accurate measurements of pipe to soil potential are recorded at intervals of not more than 2 metres.

British Gas' unparalleled knowledge base of coating faults, corrosion and pipeline survey techniques has been used to develop an integrated pipeline monitoring and inspection regime based on the assessment of risks and consequences of failure for individual pipelines.

4. Internal Stress Corrosion Cracking of Pipelines Carrying Reformed Towns Gas

In the late 1960s, ERS was involved in investigations into a number of leakage failures in pipelines which had been exposed to wet reformed towns gas following the breakdown/inoperation of drying plant. The cracks giving leakage were mostly circumferential and located near girth welds at low points in the pipeline. The path of the cracks through the steel structure was transgranular and did not resemble those in any known viable cracking environment at that time.

The work at ERS concentrated on the reproduction of the cracks found in service. Specimens from pipeline steel samples were exposed to slow strain rate tensile tests in cells enabling exposure to water equilibrated with a range of gas compositions reproducing those in the affected pipelines. The cracks were reproduced in specimens which were exposed in water equilibrated with carbon monoxide and carbon dioxide. These tests were supported by electrochemical studies which indicated that the carbon monoxide inhibited the general corrosion reaction of steel in the carbon dioxide saturated water. However, the application of a tensile stress to the steel caused local breakdown of the inhibition, and consequent localised corrosion produced cracks. The severity of cracking was increased by raising the partial pressure of carbon monoxide and by the presence of oxygen in the solutions. The threshold stress for cracking was found to be very low in the range 20-39% of the yield strength of the steel.

In these circumstances, the best means of avoiding cracking was to ensure that the gas was dried to a dew point low enough to ensure freedom from aqueous condensate in the pipeline, and this was implemented. The subsequent discovery of natural gas in the North Sea and conversion of the system to its use ensured that no further internal stress corrosion cracking could develop in the pipeline system.

5. External Stress Corrosion Cracking of Pipeline Steels

After the work on internal stress corrosion cracking of pipelines in the late 1960's, British Gas became aware of similar problems arising on the external surfaces of pipelines in America. Investigations into the factors involved in this phenomenon began in 1970, centred largely around the expertise of Arthur Brown and Mike Dale.

Electrochemical work initially investigated a range of alkaline solutions of carbonates. Eventually carbonate/bicarbonate solutions were also investigated and these were found to be more productive of cracking conditions. An extensive programme of stress corrosion tests was run on specimens from a range of pipeline steels, using slow strain rate tensile specimens, four point bend specimens and cantilever bend specimens. These latter were stressed in a manner to represent slow stress fluctuations such as arise in pipelines exposed to pressures which vary with gas supply/demand through the day.

The role of stress, temperature and time on the development of cracks were investigated and incorporated into a model of crack growth in a pipeline. This model showed good agreement with the time-scale reported for failures of pipelines in the USA and elsewhere. It enabled the level of risk in particular pipelines to be assessed on the basis of their operating conditions; stress, temperature and wall thickness. This enabled inspection schedules to be defined for the operation of crack detection pigs in pipelines deemed to be at risk of crack growth.

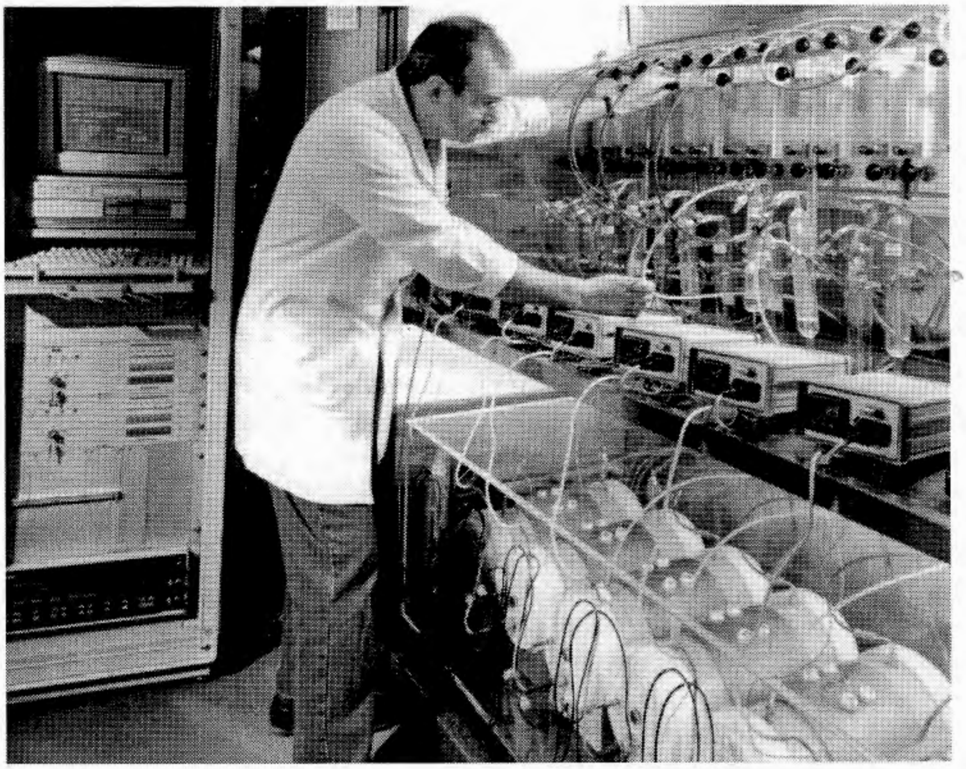
The work also indicated the means to help prevent stress corrosion conditions arising on pipelines. The occurrence of cracks under areas of coating disbondment indicated the need for optimum coating adhesion and their resistance to cathodic disbondment in service on cathodically protected pipelines. This resistance to disbondment was achieved more readily with epoxy powder coatings than with the traditional coal tar coatings previously used on pipelines up to that time.

The role of elevated temperature in creating the conditions for the initiation and growth of cracks indicated the benefits of using after coolers at compressor stations. The overall lower temperature of operation of the UK pipeline system was seen to be beneficial in reducing the susceptibility of the system to stress corrosion. The role of cyclic stress of small amplitude and low frequency in reducing the threshold stress for cracking indicated that benefits could be obtained by minimising the cyclic component of stress in pipelines by maintaining gas pressures as near constant as possible in pipelines otherwise susceptible to stress corrosion.

The work at ERS on external stress corrosion cracking was completed in 1979 when the model developed indicated the overall low level of risk for the UK pipeline system. No further work on stress corrosion cracking of pipeline steels was anticipated. However, this situation changed in 1988 when some failures were reported in pipelines in Canada. These occurred on pipelines operating at quite low ground ambient temperatures, certainly lower than those required for the cracking caused by carbonate/bicarbonate solutions.

Examination of examples of cracks found on Canadian pipes showed that the cracks were quite different to those associated with the carbonate/bicarbonate environment. Notably they were filled with quite thick layers of scale had a mixed path through the microstructure of the steel. Reports of the local environments in the area of cracking indicated that the solutions responsible were slightly acidic groundwaters and containing carbon dioxide from air trapped in porous soil.

This stress corrosion cracking system is currently under investigation at ERS and at several laboratories in North America. It is intended to establish the effect of control variables on the occurrence and kinetics of cracking to define how relevant it is to pipeline operations in the UK and Europe and if necessary to help establish effective control measures to promote safe pipeline operational procedures.



Noel Palmer adjusting an experimental rig in the corrosion laboratory used to examine the resistance of lined pipelines to "sour-gas" corrosion.

HISTORY OF ON-LINE INSPECTION AT ERS

by Colin Braithwaite

1. Introduction

It could be said, without stretching too much of a point, that the gas industry's involvement with intelligent pigs originated with the message-carrying capsules propelled by vacuum developed by William Murdoch at the beginning of the 19th century for use in the Soho foundry workshops and later taken up on a large scale for use in department stores.

However, the first modern consideration of intelligent pigging at ERS took place in 1968 and was focused by the requirement in the first edition of the IGE high pressure pipeline code (IGE/TD1) that pipelines operating over 350 psig (24 bar) should be hydraulically tested every five years.

The logistic implications of such a requirement for the transmission network were clearly very serious and consideration began to be given to the possibility of a suitable mobile NDT system to inspect pipelines without removing them from service.

2. Linalog Trials

A first generation pipeline inspection tool was being put into use in the USA and, following a proposal from East Midlands Region, arrangements were made to ship a tool to the UK for a preliminary set of trials. The tool in question was the Linalog corrosion survey tool developed by AMF Tuboscope Ltd.

This tool worked on the magnetic flux leakage principle with an axial flux induced into the pipe wall by a battery powered electromagnet. A simple analogue tape recorder recorded any flux leakage signals picked up by sensors mounted in large shoes arranged between the poles of the electromagnet.

The magnetic flux was coupled into the pipe wall through rather stiff bristles. The technology was based largely on an earlier inspection system developed for oil well casings.

The tool arrived in the UK on 18 March 1970 and inspected an 18 mile section of the 18 inch Kettering to Leicester East Midlands pipeline. It was subsequently pulled through a 300 ft section of linepipe provided with artificial defects laid out at the back of ERS. Russ Lumb and David Howard were the major players at ERS.

This first use lead on to a much more extensive programme of evaluation covering 350 miles of service pipeline plus a number of pull-throughs. Three different variants of the tool were involved. David Howard also visited the USA to obtain feedback from other users and talk to producers of the potentially competitive tools that were already emerging.

These trials covered the period 1971-1973 and were later accurately characterised by John van der Post as an "indifferent success" - meaning that the trials were successful but the results were indifferent.

3. The First British Gas Intelligent Pig

3.1 Feasibility and Development

As early as in 1968, Jim Parry produced a general specification of the requirements for an intelligent pig. This was later expanded by David Howard to produce a preliminary specification for the sizing requirements of an inspection tool and discussions were held with AMF Tuboscope to interest them in the development of their tool to meet this specification and overcome what were seen as the existing tool's major limitations, i.e. poor defect sizing, lack of ID/OD discrimination and poor dynamic performance leading to significant defects being missed altogether. These discussions came to nothing and it was rather reluctantly accepted that if we wanted a better inspection tool particularly one good enough to replace hydrostatic testing we would have to develop it ourselves.

Keith Richards took charge of the project, David Howard continued his involvement in Linalog trials and began to produce initial design studies of test vehicles.

The need for controlled testing of any system was paramount and since the introduction of real defects into the corporation's pipelines could not be countenanced, the decision was taken to build a 24" test loop at Low Thornley, since, at that time, 24" formed the major UK HP transmission mileage. Jim Parry took charge of this project in mid 1972.

Lewis Morgan, the first man recruited specifically for on line inspection work, started a programme of basic studies into the physics and design of magnetic inspection systems in May 1973. The group working on on line inspection remained small through 1972 and 1973 and in retrospect it appears that although the decision to pursue an in-house development (making maximum use of sub-contractors) had crystalised by mid-1972, little happened to make the project take off until mid-1974. This perhaps reflects the time taken - always long in the gas industry - to obtain financial approval to spend money on large projects and recruit staff.

A critical event was the teach-in for the Production and Transmission Committee of the industry held at ERS in September 1973. The experience with the Linalog trials was summarised and the Station impressed all concerned with the grip it had acquired of transmission pipeline engineering. In addition John van der Post and Keith Richards produced a paper in 1973 putting forward a five year costing for producing a limited range of flux leakage tools. This formed the necessary basis for approval to proceed with the development.

Brian Bennett Cowell Celebrating the 1,000th pig run at Low Thornley. Mike Oswell, Joe Hodgson, Brian Bennett Cowell, Mick Ford (OLIC), John Simpson (OLIC) and Billy McEvoy (OLIC driver).

While this period produced little in the way of engineered hardware, it was a period of rapid growth of our state of knowledge of the physical processes involved, absolutely essential for the rapid implementation into engineering to come a little later. A combination of experimental measurements, mathematical modelling and sensor developments laid the foundations for a burgeoning knowledge base researched by the team subsequently employed.

By early 1974, the formative period was coming to an end. A 24" test loop had been commissioned at Low Thornley - a facility unique in the world, then and for a long time - the Linalog programme and discussions with many leading NDT centres around the world had given a clear view of both the potential of the magnetic flux leakage system and the engineering limitations of the first generation tools. While magnetic systems for detecting corrosion continued to be worked on at ERS, it was realised that systems for detecting general and pitting corrosion and systems for detecting crack-like defects needed different technologies. (*See Footnote)

In addition, fracture mechanics studies into pipeline failure led by Geoff Fearnehough and Ernie Shannon had given the necessary insight into the defect detection and sizing capability needed. Bill Pallen carried out a number of engineering and design strategy studies in 1973 and correctly identified the most difficult future problem as accurate defect signal recognition.

The first magnetic pig at ERS was designed during February 1974 by Dave Howard and Lewis Morgan. It was a 24" two module device with a magnetic module (MTV1) and an instrument module (ITV2) housing a tape recorder and battery pack. The pig was put together quite quickly (6 weeks was always boasted of later) as a test bed for NDT options.

Early pull-through capers using a crane as winch were displaced by a properly designed 24" pull-through with integral winch built by Jim Parry. In using the ERS crane as the motive power for the early pull throughs, the project team gained skills in diplomacy in trying to persuade Ronnie Dixon, the crane driver, to turn out for runs at all hours. This became notorious and at one of the ERS Christmas concerts, the compere jokingly attempted to call the OLI team back to ERS for one last urgent pull through on Christmas Eve.

By the end of 1974, an embryonic multi-disciplinary design group was in place. Ernie Shannon had been appointed as Group Leader following the illness of Keith Richards, Ernie Holden and Martin Morey were working on the electronics and Ian Smith had been recruited to add a bit of analytical rigour to the mechanical engineering. Edward Glennie was recruited from the Maths Group to assist with mathematical studies of flux leakage. Jim Parry was responsible for pig manufacture and pull throughs.

Even at this early stage, it was clear that the current generation of pipeline inspection tools were only capable of detecting anomalies and what was required was a system capable of collecting sufficient information about each anomaly to determine its size. This would enable the significance of the feature to be established using criteria from significance of defect studies.

*** Footnote**
The solution identified was to approach the AEA at Harwell to carry out basic investigations into NDT systems suitable for detecting crack-like defects. The end product of these investigations was the development of the high angle ultrasonic shear wave technique. The incorporation of an ultrasonic sensory system was, however, a development that took place after the project moved to its new quarters at Cramlington.

3.2 Manufacturing the Prototypes

In early 1975, Colin Braithwaite joined the team to lead the mechanical engineers in designing the actual pipeline vehicles and Gordon Pickard was appointed to direct the efforts of the growing electronics team and produce electronics packages which would collect and store inspection data on-board the vehicles designed by Colin and built by Jim Parry. This was an example of 'concurrent engineering' put into practice even before the term had been invented.

David Howard left ERS for the transmission maintenance base at Ambergate to start preparations for the operation of inspection pigs in the NTS.

Naturally targets had been set for the teams which far exceeded what was possible. It had been recognised that to make rapid progress, some leading experts would have to be commissioned to undertake key elements of the programme, particularly in electronics engineering. Hence an outline specification for a robust multi-track tape recorder was written on one side of an A4 sheet by Martin Morey and Ernie Holden and led to the highly successful development of a purpose designed recorder which is still in regular service today. A small aerospace company, Hanbush, had the expertise and the confidence to undertake this development. The recorder was designed to be configured as an analogue machine to record on 24 tracks (subsequently 28 and finally 32 tracks) and alternatively to record digital data distributed across all tracks from several hundred inspection sensors. At that time, digital magnetic tape recording was a new and untried concept in the UK.

It was this recognition that only digital design methods could provide the capacity to accommodate more sensors than there were tracks available on tape recorders, that made it possible to develop an inspection system which was capable of 'sizing' defects.

The electronics team generated a more substantial specification for a digital data acquisition system which led to a contract with a small company called Warren Point, based in Welwyn. They produced a 78 channel prototype which worked, and a more complex 240 channel prototype which did not and very nearly led to the company's failure. John Van der Post wanted to steer the team towards a company which was big enough to undertake the development and yet was not so big that it would take it over. Gordon Pickard had been introduced to Microconsultants, a company in Newbury which had developed digital data recording systems for the electricity industry and were at the forefront of television picture processing via an associate company, Quantel. The association with Microconsultants proved to be highly successful, the ERS electronics team effectively acting as project managers to a large resource of skilled engineers.

SE Labs, part of Thorn-EMI, were given a contract to develop a tape replay machine which could be used in the field and in the laboratory. Martin Morey and David Nutton managed this contract in between researching the fundamentals of digital recording with Dr Barry Middleton at Manchester Polytechnic, (now Professor of storage technology at Manchester University).

In contrast to the extensively subcontracted development route necessarily followed by the electronics team - necessary because most of the country's electronics skills were in the aerospace firms of the south of England - the mechanical development was nearly self-sufficient. The need for the mechanical hardware to interface with the pipeline partly dictated this, but it was facilitated by the strong mechanical engineering traditions of the NE which permitted an experienced team to be built up rapidly by recruitment from Vickers, NEI, etc. Ralph Lowe, Malcolm Wayman and Dave Wright joined ERS in 1975 via this recruitment route.

The initial test vehicles continued to be used as test beds for sensor configuration, bristles and magnetic circuit development. Dave Howard's original philosophy was retained, so that drag was reduced by mounting the magnetic circuit on a resilient suspension and using the wheels to take as much as possible of the vehicle weight. This was one of the major lessons from the Linalog trials. However, the self-centering linkage of MTVI was abandoned in favour of simply springing the magnetic circuit elements against the pipe wall and hanging the instrument vessel in the middle. This left the maximum volume for the electronics, although not enough to satisfy the electronic engineers.

A major attack was made on the problem of sensor suspension as the original carrier shoes showed a persistent tendency to bounce off the pipe wall and even be ripped off the pig entirely.

After many ideas and much high speed camera work on the reciprocating rig, the current low mass system was arrived at and has proved to be one of the more stable design elements on the pig.

The need for an additional set of sensors to facilitate ID/OD discrimination of defects was identified at an early stage. This had a considerable effect on the vehicle train layout as it was necessary for the auxiliary ID detection sensors to be remote from the magnetic circuit and, for reasons associated with the limitations of the on-board electronics, to be in advance of the main defect sensors. This could only be achieved with the ID sensors mounted on the instrument module which had then to lead and act as the traction module with the drive cups mounted on it. This was not an ideal mechanical arrangement. The towing coupling between the modules had then to cope with all the magnetic drag from the magnetic module and deal with side loads in bends. It was not until much later in the project that this electronic limitation was escaped and the mechanical engineers achieved the design objective of combining the drive and drag in the leading module.

The development of the inspection pig drawing office as a separate entity from the existing ERS rig design office is interesting. The ERS drawing office was used to providing a rig design service on a customer-contractor basis with Bill Pallen, who was then in charge, closely controlling both what was done and how it was done. This was not entirely satisfactory for other development engineers who wished to control the design process themselves. David Howard's response was to set up his own private drawing office using contract draughtsmen housed in a portacabin in the back yard of a local contractor - Swinney Engineering - who were utilised to manufacture many of the initial development pig components.

Colin Braithwaite inherited this arrangement and the staff in the 'private' drawing office grew to four: Dick Douglas, Ian Burns, Chris Reid and Dennis O'Neill, all competent if idiosyncratic characters who made a considerable contribution to the early development.

Swinney Engineering also made a major contribution and Jim Parry, who was responsible for pig manufacturing and assembly, developed a close working relationship with the Swinney staff who were unsurpassed as a contractor, in their general helpfulness. Swinney's factory - since vanished - was sited in the town centre of Morpeth and had a unique ambiance, not all of which was due to the fact that part of it was sited in an old church.

As the pig drawing office grew, it was moved down to another portacabin on the ERS site and then to the upper floor of a small factory owned by Norstead Engineering, part of which was rented for Jim Parry's burgeoning pig assembly and procurement office. Norstead were (and are) just north of ERS at the entry to Burradon Village.

By this time (1977) the whole OLI project was growing in staff and becoming rather a cuckoo in the nest at ERS. The problem was temporarily resolved by renting a large linked array of portacabins - known as Portacabin City - into which the OLI staff moved.

Whilst the electronics team was monitoring major external contracts, it was developing all of the peripheral systems and equipment needed for the inspection vehicle itself and for test and commissioning during development and eventual manufacture. Ernie Holden had found a local family-run company which could wind sensor coils and injection mould them into an assembly. This company still manufactures all of the main inspection sensors. Derek Storey and Charles Gregory were set the task of developing a line marker which could transmit to the inspection vehicle moving directly below the antennae and Bill Frain, Andrew Smart and Peter Hutchinson set about designing, building and testing battery packs and distance measuring wheels. Bob Chapman and Norman Carrick were responsible for test systems; this association led to the development of a range of valuable tools which were used to quantify the performance of digital data recording systems.

3.3 Pipeline Inspection Trials

The efforts of the physicists, mechanical, electronic and manufacturing engineers produced a number of test vehicles of gradually improving design which were used in a series of trials commencing in 1975. The trials were used partly to obtain pipeline inspection data and partly to obtain environmental data on the dynamic behaviour of the inspection vehicles.

Two pipelines were chiefly used, the 24" Ambergate-Pentrich line and the East Brierley-Hopton top line. The inspection runs used a 14 channel 'Pemco' tape recorder and the environmental runs a 7 channel 'Hanbush' recorder.

These 'development' trials continued through 1975, 1976 and 1977 until the first 'service' trial in the East Brierly to Hopton Top pipeline took place in the summer of 1977, in which the development group undertook to report the inspection results to the transmission operating staff. This was the culmination of the combined efforts of what was by then about 120 staff.

The initial service was based on simple analogue recording and in truth was no better than commercially available tools. However, this initial success soon led to the introduction of the first 78 channel digital system into service, although Mike Sharp was known to have carried the analogue system to field trials in the boot of his car for many months - just in case.

This early success was consolidated with the eventual introduction of the data acquisition unit developed by Microconsultants. There was also a notable section of pipeline between Seebank and Framton-Cotterel which proved to be badly corroded as a result of sacrificial anodes being disconnected for a long period. This produced good PR for the project. These successes combined with the quantitative nature of the inspection service and growing need to demonstrate that the Company had an acceptable alternative to revalidation by periodic hydro-testing led to the project and design teams moving out of Portacabin City at ERS and establishing the Inspection Centre at Cramlington in June 1979 under its director, Gerry Clerehugh.

4. A Retrospective Overview

Whilst undeniably the whole project has been very successful, there were inevitable hiccups, minor tragedies and near disasters along the way. Warren Point nearly went to the wall as a direct result of the high risk contract work, Hanbush eventually went into receivership, was bought by GEC Marconi and moved to Nailsea with the loss of several key staff. Mostly it was the low technology items which caused the majority of problems. Batteries, cables and connectors were the main culprits, though long lead times, sudden obsolescence and non-availability of new items came a good second. Fortunately, serious accidents were rare. In the early days, a line on the Isle of Grain was inspected with a compressor providing the motive power. The pig stuck at an obstruction and the retrieval pig sent down the line wrecked the inspection pig and on-board electronics. This led directly to the introduction of 'deformable' profiling pigs which are now used routinely. Several years ago, one 24" pig stuck in an illegal bend in the line between Winnick and Warrington. The driving cups on the pig blew over as designed and North West Region cut out the pig and returned it still in the section of pipe within 48 hours.

Working on inspection pigs carrying very strong permanent magnets caused special assembly problems and some safety hazards. Many watches were magnetised and many people embarrassed at supermarket check-outs when it was discovered that the magnetic strips on their credit cards had been 'wiped'.

At least one anecdote has survived. One day, David Howard was carrying pig magnets in the boot of his car when the exhaust system fell off the vehicle. He headed immediately to the local exhaust fitting centre where the fitter was most surprised to find the new exhaust system leaping out of his arms, into the air and sticking remorselessly to the floor of the vehicle through the influence of the magnets in the boot.

Managing and working with a large multi-disciplinary project team had its own problems. Life often seemed to be a struggle of the disciplines; physicists always demanded an unrealistic number of sensors on the pigs, electronics engineers needed too much pressure vessel volume and too many connectors. Mechanical engineers always thought components needed a little more meat on them just in case. On one occasion the tolerances were just too tight. A complex electronics pack had just been completed, with hundreds of fine wires having been soldered to bulkhead connectors. The pack was then pushed into the pressure vessel by the mechanical technician, only to find that it had wedged in the tight bore of the pressure vessel. Feeling unable to take responsibility for removing the delicate package, the technician handed over responsibility to the electronics engineer. He in turn exercised his skills and applied his boots to the pig, pulled with all his might, only to rip the bulkhead off the package leaving a mass of torn wiring behind.

The senior management of the project by Gerry Clerehugh and Ernie Shannon should also be mentioned. As a double act, they were effective, both in maintaining pressure on the design teams and producing support from the company's funding committees and executive. A constant stream of favourable reports flowed down to London and money flowed back. However, the dreaded Monday morning progress meetings which Ernie Shannon ran were often quite stressful as Ernie could make the windows rattle when things had not gone well. This was known in the project team as "putting his Ian Paisley collar on", a reference to Ernie's Northern Ireland origins and style of 'hell fire' oratory.

Overall, however, the team were strongly self-motivating and, by the time the project moved up to Cramlington, the development was well on the way to success. There was still much to do in improving reliability, diversifying the size range, increasing the range and adapting the tools to offshore and oil pipelines. The development is now the basis of a £20 million per annum business and generates a substantial return to the Company. Additionally, in 1989 the management team of Gerry Clerehugh, Ernie Shannon, Colin Braithwaite, Jim Parry and Gordon Pickard went on to win national recognition in the form of the McRobert Award Gold Medal for innovation in engineering. We think John van der Post would have been pleased.

METERING AND LARGE VOLUME CONTROL

by Roger Norman

1. Introduction

The story of high pressure flow measurement and control started with the construction of the National Transmission System (NTS) and there are four reasons why flow measurement at high pressure then assumed importance to the Company. Firstly at the beach where the gas is purchased from the Oil Companies, the cost of purchase is determined by the accuracy of the shore terminal meters. Secondly at offtakes where gas is supplied from the NTS to Regions, flow measurement performs the important function of metering the daily takes of the Regions. Thirdly these measurements also provide information which allows Regional leakage rates to be determined. Finally flow and pressure control of the NTS enables daily and seasonal demands to be met in the most efficient manner (i.e. at minimum cost and with maximum security of supply).

However British Gas first encountered problems with metering arising from a rather different source. Calculations of the difference between the inflows and outflows of gas to the transmission system showed that the "unaccounted-for" gas was of the order of 10%. Since the system was of all welded construction it was impossible that these differences were due to leaks and therefore the source of this discrepancy had to be at the flow meters. Errors of this magnitude were unacceptable since they prevented estimation of Regional leakages, certainty in the amount of gas being purchased and the efficient operation of the transmission system.

This problem of unaccounted-for gas led to the establishment of a flow measurement team at ERS led by Peter Jepson.

2. Orifice Meter Problems

The meters used on the transmission system were almost all orifice plates, in which the gas is forced to flow through a hole whose diameter is typically half that of the pipeline bore. This causes an acceleration of the gas which results a pressure drop which can be measured. Studies of the installed plates indicated that there were many faults with them. One of the most obvious was the accumulation on the front face of debris and grease shed from valves upstream. Studies at ERS showed that these effects would cause the calculated flow to be less than the true flow.

A further defect identified was lack of upstream square edge at the entrance to the orifice bore, a defect shown to result in under reading of the meter. The square edge is difficult to measure and so an edge sharpness measuring device, called the Orifice Radius Inspection System (ORIS) was developed at ERS. The equipment works by carefully applying a thin piece of lead foil to the square edge to obtain an impression of the edge. The radius can then be measured by inspecting the impression under high magnification. This development led to the establishment of an inspection centre at Hinckley, at which all the Company's plates together with those of most of the North Sea producers, are checked. In addition, the Gas and Oil Measurement Branch of the Department of Trade and Industry together with several suppliers use the ORIS equipment themselves.

A problem with lack of plate flatness was also identified and this again led to under reading of the meter. The problem was examined by carrying out flow tests at ERS and by developing a theory to explain the observed effects. It was found that if meters were vented (or repressurized) too rapidly during outages for inspection, very high differential pressures could be created across the plate and could cause plate bending to occur. This theoretical work led to the realisation that because the operating differential pressures in the UK were twice those employed in the US, plate bending during operation was occurring. Clearly this cannot be detected by a physical inspection during an outage but can be prevented at the design stage.

Much of the early meter testing work was carried out at Low Thornley. The downrating of the site and the transfer of high pressure work to a new site at Bishop Auckland presented an opportunity to enhance ERS's ability to provide a high pressure, high volume test site with very high accuracy reference metering. The test equipment at Bishop Auckland is therefore traceable to the UK National Standard which is based on the fundamental quantities of mass and time, located at the National Engineering Laboratory.

From the metering studies a rigorous flow measurement manual for the transmission system (P&S/MI) was written and the use of this standard has resulted in the reduction of the unaccounted-for gas to well under 1% and to a level which is considered to be acceptable. The work has also been presented in publications and fed into British and International Standards and has led to the general raising of standards in orifice metering.

3. Later Studies

Subsequent studies have been made into the plate eccentricity within the pipeline, since proposed standards were found to be impossible to meet and into the basic coefficient to be used in orifice metering calculations. ERS participated in an EC led project to generate a new data base for the recalculating of the coefficient. The work involved about a dozen laboratories through Europe including the ERS Test Facility at Bishop Auckland where meter runs on 10" and 24" diameter pipe were tested. This work will lead to a further refinement for orifice meters to help meet the demands of users.

4. Turbine Meter Studies

While orifice plate meters formed the bulk of the equipment studied, other flow meters have not been neglected and turbine meter studies have yielded important information. These investigations have primarily been connected with installation effects where errors can be present without them being appreciated. This tends to arise in industrial installations where space can be at a premium and upstream flow effects lead to meter error and potential loss of revenue to the Company. The results of the studies have been incorporated in Company standards and IGE recommendations (e.g. IGE GM1 and BGC/IM 112).

5. Large Volume Flow Control

The associated area of control of the flow has been the subject of extensive study at ERS and has resulted in the development of a number of control systems which have led to significant gains to the efficient operation of the transmission system. Three such systems are described below:

The introduction of stricter safety standards related to the presence of population near pipelines led to the development of a control system by Bill Arden and Andy Lees to maintain the pressures in a pipeline at their optimum without breaching imposed pressure limits at specific points. The electronic hardware and software was developed and field-trialled by ERS and has been implemented at a number of Regional sites. It has resulted in significant gains in throughput and storage and in deferred reinforcement costs.

A subsequent development was an offtake control system called GasControl 2000. The system uses industrial process controllers with flow and pressure measurements to perform all regulator and slamshut control functions on an NTS offtake. This development was first installed at the Pannal Offtake and subsequently became a company standard. It enables throughput and downstream linepack to be optimised as well enabling remote operators to change the flowing stream and carry out a number of safety checks. The benefits from this work show themselves as deferred expenditure and enhanced safety.

The control of Pressure Reduction Stations (PRSs) has also been investigated and improved. Normally these stations are entirely pneumatically controlled and due to the nature of pneumatic systems, the normal output pressures can be significantly below the safety limit. This can result in reduced operating pressures and safety margins that are in reality less than those which are believed to exist. Studies of the behaviour of Axial Flow type regulators identified a new way of controlling them termed Tandem Control. This is a very low cost change to a PRS but has produced benefits in improvements to slamshut settings and in tighter control of outlet pressures, reduced overpressure during regulator failure and enhanced safety.

6. Future Investigations

The most recent developments in control are related to a wider look at high pressure systems and consideration of closed loop control of entire Regional networks. These are

complicated interconnected systems which offer opportunities for modern control techniques to enhance performance. The areas that will benefit are: diurnal linepack storage, increased throughput, reduced heating costs at PRS's and deferred investment in reinforcement. Improved control normally has low implementation costs in relation to the benefits and is a continuing area of study.

STRUCTURAL ENGINEERING

by Derek Brown and Les Mercer

1. Introduction

Structural engineering has long been a corner-stone in the fundamental make-up and success of ERS. John van der Post perceived the vital role of a well founded numerically skilled engineering team right from the outset. He recruited Derek James in September 1965, during the Fulham period, with the task of building an effective and balanced team. It was to have a sound academic basis but, at the same time, be capable of applying its skills in a thoroughly practical manner to the then rapidly changing technology upon which the gas industry was based. With his background in aircraft and hovercraft engineering, Derek set to with a will to establish a fine team which continues to play a key role in the ERS portfolio to this day. The new presence was something the industry had not previously experienced. It led the way in fulfilling John van der Post's conviction (to quote him) 'if work at ERS is to be useful, it must be applied, and in engineering, research is applied through design'.

Thus, the early period targeted reforming plant. Close links were forged with industry operational personnel and with the design teams of the principle plant supply companies. As time went by, attention moved on to high pressure storage vessels, to wide ranging aspects of transmission engineering and later, to the offshore area. Notwithstanding the considerable and urgent demands of the early reforming period which took up much of the time of Derek and his embryo band of senior staff, rapid progress was made in assembling a capable, experienced and credible team. Structural engineering had long been a basic facet of north eastern life and local engineering companies, such as Vickers, C A Parsons, Reyrolles and Clark-Chapmans, provided a stream of well qualified engineers. The accelerating decline of the aircraft and nuclear industries yielded other specialists, usually from further afield. The outcome was the rapid establishment of a strong and experienced team, with the will and the tools to grapple with the many new and exciting problems then facing the fast changing gas industry.

A visit by Board Members to ERS – Derek Brown helps the chairman nod-off after lunch.

2. Early Classical Techniques

Structural engineering is concerned with the accurate analysis of stresses in components with complicated shapes, made from materials often with non-linear properties and subjected to complex loading. At ERS, it is applied through code development and specialised 'trouble shooting'. To be fully effective it involves working closely with related specialities, such as metallurgy, welding, non-destructive testing, fracture mechanics and, particularly, with experimental proving, since the correlation of theoretical analysis with experimental measurement is an essential step in validating any theoretical model.

It is remarkable how analytical methods have changed over the last twenty-five years. In 1967 stress analysts relied heavily on classical analysis methods using slide rules and electro-mechanical calculating machines. Classic texts by Roark and Timoshenko provided the basis of almost every piece of work and "back of the envelope solutions" frequently took on a literal meaning. The first electronic desk calculator, about the size of an electric typewriter, appeared at ERS in 1967 and the first computer in 1968. Before that time, structures staff, being anxious to adopt the new technology provided by computers, used a machine at Grubb-Parsons - a local engineering company, now, like so many others, defunct. Each afternoon David Wild, who at that time constituted the entire ERS computing department, would collect data input cards from around the station and take them by car to Grubb-Parsons for processing.

Experimental verification involved painstaking strain gauging of components. This was both expensive and time consuming. Furthermore, judicious placing of the gauges was required if the maximum stresses were to be recorded.

3. The Finite Element Method

Following the introduction of computers, it became progressively easier to tackle problems using numerical methods of solution and, of these, the finite element method was predominant. Finite element analyses have the advantage that displacements and stresses are predicted throughout the whole structure and the effect of changes in component loading and geometry can easily be taken into account.

The principle of finite element analysis is quite simple. The structure to be analysed is sub-divided into a large number of elemental units - the mathematical equivalent of a Lego model. Equations are set-up describing the stresses and deformations of these simple elements under load. From these, the solution of the displacements and stresses in the complete structure are obtained using the powerful computers which are now available. This apparently simple technique does, however, demand a very high level of skill and experience to produce a valid model of the structure and the loads acting upon it, and then to analyse and interpret the results correctly. Input is required from experienced engineers, mathematical modellers and computer programmers. The result sometimes leads to conflict as the varying priorities placed by these specialised skills come to the fore. Thus, the extensive computer programming expertise, originally at the London Research Station (LRS), complained loud and long about the inefficiency of the ERS approach to putting the essential engineering requirements into computer terminology! Dennis Edward, a key player on the ERS team, bore the brunt of the 'attack'. His solutions may not have been the most elegant, but they worked and found ready application within the industry.

Over the years, enormous strides have been made in both software and hardware with engineers consistently showing an insatiable appetite for more and more computing power. That was as true twenty five years ago as it is now. The first ERS computer, an IBM 1130, was rapidly outgrown and for a number of years the group used the much larger IBM machines at Newcastle University using a land line link.

In the early eighties, the first of a series of VAX computers was installed at ERS to provide a platform for a range of commercial engineering software which was much more powerful and sophisticated than home produced software. Looking back, it now seems incredible that, in those early days, structural engineers were expected to write their own software for solving problems using the finite element method. Despite these reservations, a derivative of one of those home-produced codes has stood the test of time and is still used as the industry's standard method for analysing mining subsidence and other ground movement effects on pipelines.

4. The Range of Work Undertaken

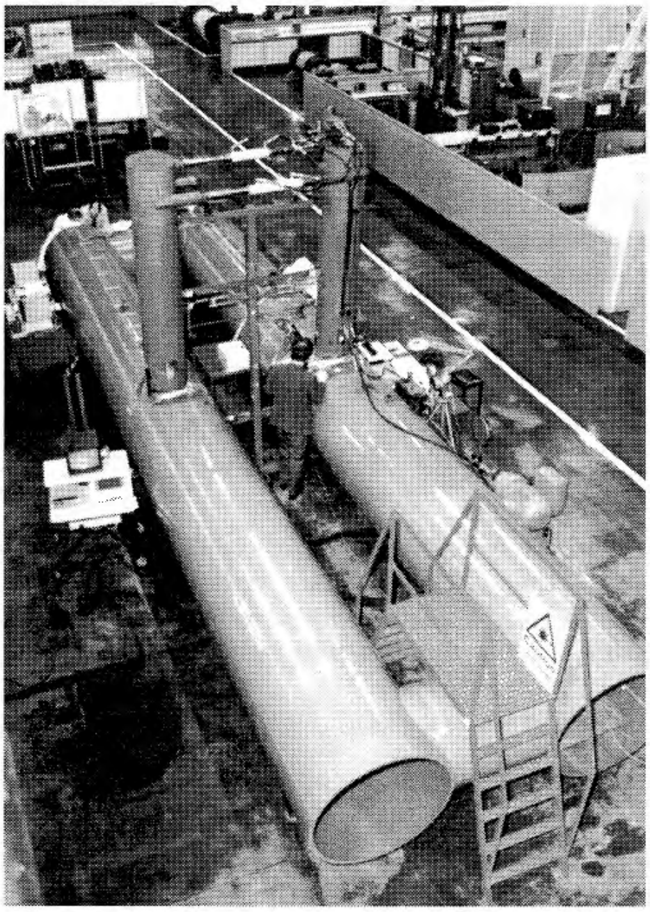
Over the last twenty five years, many hundreds of individual tasks have been undertaken. The vast majority have been quite small jobs, each typically requiring a few months of work. But there have also been a considerable number of major projects, which have had a significant effect on the company's operations and profitability. A few examples may serve to indicate the way in which structural analysis techniques can be applied to operational problems.

A significant proportion of the transmission system was laid in coal mining areas and the response of a pipeline to ground movement resulting from mining is a complicated phenomenon. It depends on such factors as depth and thickness of the coal seam, overburden characteristics and properties of the pipeline. A structural model was therefore developed not only to predict the response of pipelines to mining operations, but also to provide guidance on preventative measures. The company benefitted in a number of ways from the application of this technology. Firstly, gas supplies are protected by reducing the incidence of serious damage to pipelines. Secondly, preventative and remedial measures can be designed to be safe and cost effective. Finally, using the predictions, British Gas has been able to put together robust technical cases supporting claims for financial compensation from the mining company. In most cases any costs arising from damage or preventative measures have been fully recovered.

British Gas is a major operator of high pressure plant. It owns more than 20,000 pressure vessels and over 17,000 km of high pressure pipelines. The company has always operated and maintained its systems to high standards and, as a result, it has enjoyed a safety record which is second to none. Failure of its plant due to intrinsic structural deficiency is virtually unknown. This enviable safety record has not occurred by happenstance. All pressurised components are purchased and operated to engineering specifications such as IGE TD/1. For many years, structural analysis has been used to provide a technical basis for company standards for design and operation. The structural engineering principle adopted in all our codes is the accurate determination of stress levels in components coupled with the imposition of limiting values of stress which are dependent on material properties and defect sizes. The key to efficient design is to allow the highest possible stresses whilst maintaining an adequate margin against structural failure. This approach has been applied to virtually all pressurised components throughout the high pressure transmission and storage system. Not only has it provided a basis for sound and cost effective design, but also for safe and efficient in-service inspection and maintenance practices.

More recently, using even more powerful computers and advanced finite element software, structural engineers have tackled an impressive array of complex problems including, for example, the analysis of explosions, impact and fire on tanks and vessels. These are notable examples of dynamic, non-linear problems in which the motion of a structure under analysis has a significant bearing on its internal stress state and in which there is a non-linear relationship between deformation and the applied load. For example, stresses developed in a pipeline which is accidentally impacted by a JCB are governed, not only by the imposed force, but also by the velocity and mass of the JCB. Furthermore the pipeline material will exhibit a non-linear stress/strain relationship when it is highly loaded and approaching failure.

One method of solving dynamic or non-linear problems is to sub-divide the loading event into a large number of time or displacement increments and treat each one as a separate analysis. This method of solution is mathematically rigorous but demanded a quantum leap in computing power. Nowadays, this is no longer a problem since ERS is equipped with excellent computing facilities and expertise which match anything available in any equivalent organisation in the UK.



Tubular Joint Test Rig – used to evaluate the effect of wave motion on fatigue failure of weld defects.

COMPRESSOR PERFORMANCE TESTING

by Jim Nisbet

1. The Function of Compressors in the National Transmission System

As gas flows through a pipeline its pressure falls due to friction against the pipe wall. This pressure loss can be restored by compressors installed at intervals along the pipeline. In this way the transmission capability of the pipeline can be increased, avoiding the cost of additional pipelines (Fig.1). Compressors are also needed to meet the variations in supply and demand patterns on both a seasonal and a daily basis, as there can, for example, be as much as six times more demand in winter than in summer.

There are twenty compressor stations in the National Transmission System (NTS), with in excess of fifty compressor units totalling 720MW of shaft power. All the above gas compressor units are based on the same design concept of three elements:

1. A gas generator
2. A power turbine
3. A gas compressor

Fig.2 shows the arrangement.

The gas generator is an industrialised version of an aero jet engine, which provides a flow of pressurised gas directed into the power turbine. The power turbine converts the energy in the pressurised gas into shaft power to drive the compressor. These three elements come together for the first time on the operational site, and this is the first opportunity to test the complete unit.

2. Compressor Unit Performance

The performance of a compressor unit is most simply defined as its range in terms of flow rate and pressure ratio (as shown in Fig.3) and the cost (efficiency) of operating at all duties within the range. The operating range must also meet the NTS demands. In addition to the seasonal demand variations noted earlier, reconfigurations of the NTS grid and changes in the supply profiles from the five terminals create further problems in meeting NTS demands.

In order to achieve optimum operational efficiency in meeting the varying NTS demands, it is vital to gather accurate and comprehensive performance data. Additionally, such data facilitates considerable cost savings in the planning of new stations and modifications to existing stations.

A significant change in attitude to efficiency has developed over the last twenty years of compressor operation, as fuel costs have increased from 0.6p (1.5d) to 47p/therm.

3. Development of Test Procedures on NTS Compressors

In 1978 ERS was requested by the Plant Operations Department (POD), to test and report on the performance of the compressor units at Diss Compressor Station, as the operators had found the site performance did not agree with the manufacturer's prediction.

A project team was formed, led by Jim Nisbet with Eddie Falcus and Gil Osborne, to test the Diss units. The tests were completed successfully, defining the actual performance of the compressors and confirming significant deviations from the manufacturer's prediction.

Following a review of the Diss test findings, the Inter Departmental Liaison Committee adopted a policy of performance testing all NTS compressor units. ERS then initiated an intensive test program, and Ian Robertson, Bob Ingram and John Hall joined the project team.

The procedures for the earlier performance tests were developed on the job and data was collected by the test operators, manually entering readings on to log sheets. The highly labour-intensive nature of testing frequently resulted in tests being curtailed before all the necessary data had been collected. Data analysis performed offsite was also labour intensive and meant that measurement errors might not be identified until weeks after the test, when retests were impractical.

To overcome the above problems a mobile laboratory was developed, employing a PC driven data logging and analysis system, and incorporating appropriate safety features to allow the system to be operated in hazardous zones. Eddie Falcus and his team take credit for the design, commissioning and operation of the mobile laboratory and for all the instrumentation, including the development of novel instrumentation techniques. A suite of computer programs to control the logging system, to analyse data on line and to present performance results digitally and graphically, was written by John Blunt. Special provisions had to be made to cater for the capacity limitations of the first generation PCs .

Over the course of time these programs have regularly been expanded and enhanced to meet the increasing demands of the end user and have taken advantage of the rapid developments in PC capabilities.

Many of the programs developed for this project are now key components in COAS (Compressor Operations and Advisory System) a system put together by Plant Operations Department, and installed on most compressor stations to optimise operation of, monitor and test the compressor units.

More than fifty NTS site tests were completed up to 1988. The tests showed that some compressors were badly matched to the operating conditions. Selected compressors were modified, in line with ERS recommendations, improving operating efficiencies by 14%, saving in excess of £1.3M/year at 1992 fuel prices. The tests also highlighted significant deviations from the manufacturer's predicted performance and substantial differences between nominally identical units. In general the operator was not aware of these differences, which is a criticism of the quantity and quality of the installed instrumentation rather than the operator. The advent of COAS, with the associated comprehensive high quality instrumentation, should enable similar problems to be readily identified in the future, in the course of monitoring normal operations, and allow the appropriate remedial actions to be taken promptly.

During this time the project team also identified the benefits of compressor optimisation, and initiated work on this topic. The procedures were developed and proved by Alan Clark, Roger Hawkins and John Blunt, and are now incorporated in COAS. By 1988 it was considered that the procedures had become sufficiently routine for the activity to be handed over to POD.

4. Rough Field Compressors

Another compressor application is for reinjection on the Rough Field, where gas is injected into the reservoir in the summer when production exceeds demand, and then released to the NTS during the winter as peak demands arise.

ERS developed test techniques into these more complex areas of multistage intercooled compressors, and tests were carried out in 1987-9. These tests highlighted and pin-pointed the cause of substantial performance shortfalls which, when rectified, allowed a saving of £1.0M in fuel cost and, of even greater importance, increased the volume of gas which could be stored in the injection season.

Tests after rectification provided the data for the compressor models which are vital elements of RUFSIM, a simulation model of the whole injection process which was designed by Barry Thompson, Phil Graham and John Blunt.

5. Turbo expanders

In the 1990s performance testing moved into a new era to determine the performance of two prototype turbo expanders. The turbo expander replaces the conventional throttling operation on a Pressure Reduction Station (PRS) with an expansion turbine which produces shaft power driving (most typically) an electric generator, the output being used by British Gas, and any surplus being exported to the local electricity board.

The tests showed that electric power could be generated at a fuel cost of less than lp/kWhr.

6. Performance Testing and Monitoring, The Future

More recently ERS has become involved in performance testing and monitoring of Combined Cycle Gas Turbine (CCGT) plant used for electrical power generation. These plants comprise large gas turbines (circa 150-220MW) driving an alternator, the exhaust gas passes through a boiler, raising steam which is supplied to a steam turbine driving an alternator. This is an extrapolation of ERS experience to plant an order of magnitude greater than our previous experience in terms of power and complexity.

Performance testing and monitoring will become more and more important as fuel prices rise, and the need to minimise the environmental impacts of plant operations have an increasingly high profile. It seems likely that regulations will require plant operators to demonstrate the efficiency of their plant and that environmental effects will have to be contained within appropriate limits. Bonuses for high efficiencies and penalties for low efficiencies may well be applied, in addition to the inherent fuel cost implications of efficiency. Such regulations already apply in some western European countries.

HISTORY OF NETWORK ANALYSIS AT ERS

by John Blunt and Norman Revell

1. Introduction

With the arrival of high pressure gas transmission mains in Britain, for both reformer gas manufactured in Britain and Algerian natural gas brought by tanker to Canvey Island, it was realised that a computer program would be required to calculate the pressure changes throughout the system. The pressure in a transmission pipeline falls from the point of supply to the offtake into a local distribution network due to the frictional drag of driving a body of gas through the pipeline. In addition the supply rate is best held steady while the offtake rates will vary throughout the day. This leads to a general fall in pressure in the pipeline when the demand exceeds the supply and a recovery of pressure when the demand is reduced. This effective available stored volume was called linepack. The ability to predict pressures in a transmission system was an operational requirement in order to provide the required pressure at the offtakes at all times. Pipelines should also be designed not only to transmit gas under the available pressure drop but provide linepack storage to absorb the daily variation in demand. The calculation by hand of dynamic pressure effects for a rapidly expanding network was not a practical proposition.

2. Transient Flow Programs

Existing programs for network analysis could calculate the pressures for steady flow conditions, the 'CONGAS' program from Canada was widely used for regional network analysis, but this new situation was by no means steady. A number of commercial programs for the computation of non-steady or 'transient flow' were becoming available, for example PIPETRAN from the USA, and some papers and books on the subject had been published. However as no totally adequate program was available in 1966, it was decided to develop a program at ERS and a mathematical method published by J.Guy of Salford University was adopted as the most suitable. The program was developed on an IBM 1130 computer using the FORTRAN language.

The British Gas transmission system at the time consisted of a main trunk line with a number of branches. Some measured supply and offtake data were obtained from the telemetry system over an eight hour period and the computer model showed good agreement with it. Further validation was obtained from tests on a short length of medium pressure main in East Midlands Gas Board, who had been independently surveying the available computational techniques.

3. CAP and DNS

The program was then further developed to cater for looped networks with compressor stations and regulators. Two styles of the program emerged, one called CAP, the Control Advisory Program and the other called DNS for Dynamic Network Simulation. CAP was designed for Grid Control operators to do day to day simulation of their transmission system through an interactive interface. This enabled them to predict the pressure variations in their transmission pipeline under the expected demand and ensured that the rate of supply was sufficient to maintain the required pressure at the offtakes. Central Control Department of Marble Arch were heavy users of the program which was installed on the computer at the London Research Station. The DNS program was intended for system design and operation studies, ran in batch mode and was distributed to the various Gas Boards to run on on their own computers. A paper on the ERS work by Mike Heath and John Blunt was presented at the IGE Autumn Research Meeting in November 1968 and being the first in Gas Industry on this subject, was considered to be a landmark in the history of network analysis.

In 1970 a paper by David Needham and John Blunt entitled 'Pipeline Network Design for Transient Flow Conditions' was presented to the International Gas Congress in Moscow. The ERS programs were sold to Ruhrgas in Germany and installed on their IBM computers for day to day system simulation and for design studies. A further sale was made to the Gas and Fuel Corporation of Victoria and installed on their Burroughs computer. Within British Gas, CAP took over the functions of DNS as interactive computing gained in popularity and computers became more powerful.

4. Network Analysis at LRS

In 1974, the maintenance of the CAP program was transferred to the Mathematics and Computing Division at London Research Station (LRS) where a team of staff were working on various programs for pipeline system design and optimisation and the PAN transmission network analysis program had just been developed. Programs for the analysis of distribution systems had also been developed at LRS, principally the PILOT program. At the time Walter Bellars was Division Manager and Tony Fincham led the Mathematics Group, names very much with us still, unlike the names of programs past!

So LRS became the centre for network analysis development. Over the next few years PAN with its superior functionality and friendlier interface steadily replaced CAP. A new program called PEGASUS replaced the PILOT program and all the 'home-grown' programs produced by the Regions themselves such as DNET and FP6. PAN was eventually replaced by FALCON to deal with a transmission system that was ever increasing in complexity. Microcomputers came on the scene and software was written to make network analysis available on very cheap machines. The SNAP program for distribution was such an example and saw a steady stream of overseas sales. The SPIDER program was developed to plot network schematics complete with results. Mathematical optimisation was put into network analysis in programs such as OTTO, which determined the best set of compressors to use at each level of demand on the National Transmission System (NTS).

From the above, the reader might think that as much invention and ingenuity has gone into the program names as the programs themselves! Most of the names are acronyms. For example, FALCON is the 'Fast Analysis of Large COnstrained Networks'; a bit contrived perhaps, but it had the right image. PEGASUS also had the right ring about its name, but it was not an acronym, though 'Program for Evaluating Grids And Stuff Under Streets' has been suggested!

5. Network Analysis Returns to ERS

In 1990, after a gap of sixteen years, the work on network analysis had a sort of homecoming when it was moved to ERS to be closer to the other engineering research activities. The operational experience at ERS has helped to bring network analysis out of its ivory tower image and apply it to some of our present day problems. For example, a recent major success has been to put mathematical optimisation into the PEGASUS program to enable it to determine the best pressures at which to supply a distribution system in order to minimise leakage. This work has been further extended to assist in the design of electronic closed loop control systems and thus complement the engineering work done at ERS on hardware and systems.

Now a new age has dawned with the use of graphical user interfaces in network analysis. There is the continuous simulation program being developed for Control Group, which will allow grid controllers to predict the behaviour of the NTS for several hours ahead and compare the likely outcome of a number of possible strategies. The program is driven through a graphics screen with menus and objects that can be pointed at. Graphs give the user meaningful pictures of grid behaviour and can be related to network schematics drawn on the screen. An even slicker approach is being used to bring continuous simulation to the Regions.

PEGASUS for distribution and FALCON for transmission are now established as the network analysis work horses (and birds) in the Company. Studies have shown that the annual benefit of such software to the Company is well in excess of £20 million. Those benefits need maintaining and can be improved on and the use of graphics will play a major part. Graphical user interfaces make programs easier to use, less costly to maintain and enable a wider range of possible engineering solutions to be evaluated in a shorter time.

Network analysis has now been with us for over 25 years and is far from being dead. Optimisation, graphics and grid control are all areas which have widened the area of application of the technique and added to its value over the years. There is still much to do, for which read the next history of ERS!

TELECOMMUNICATIONS

by Ian Whiteley

1. Introduction

The initiation of activity at ERS in the telecommunications arena can largely be attributed to the HQ C&I Engineer at that time, the late John Goodman, and also to the late Tom Lucas, who managed C&I policy. They recognised that there was a need to obtain specialist support on telecommunications matters in the same way as for instrumentation matters, which was already taking place. The Communications Section was established at the beginning of 1975, with the appointment of Ian Whiteley and Mark Al-Nuaimi. The early work of the Section was concerned with mobile radio. We shall see later that as some of the technical issues were being dealt with, there emerged a satisfying fit with the business needs. Almost one and a half decades later this contributed to the Company establishing a central team to implement the Company Field Systems. Even today a major part of the Section's work is in the general domain of mobile radio.

2. Radio Regulatory Issues

When developments in the size and power consumption of electronics in the middle 1950's opened up the possibility of widespread civilian use of mobile radio, it was quickly realised that there was a need to formalise the interface with the Government Agency responsible for licensing the use of radio apparatus under the 1949 Wireless Telegraphy Act The Post Office in those days. A number of organisations had similar needs of being able co-ordinate field operations, and to manage their personnel who were normally away from the office. The three nationalised fuel and power industries (Gas, Coal and Electricity) found it expedient to co-ordinate their interface to the licensing authority. This led to the formation, in 1956, of The Joint Radio Committee of the Nationalised Power Industries - or the JRC as it is widely known. The JRC continues to fulfil a vital role. Support to this organisation from the Communications Section will be seen to have been an important activity.

Ian Whiteley represented ERS as research adviser to the superior governing committee, known as the 'Main Committee', and then following the establishment of the R&D Sub-Committee became the first chairman of that sub-committee. There was much work to be done on behalf of the JRC during the 1980's. The International Telecommunications Union periodically re-evaluate the allocation of the radio spectrum between the various types of service, and the results of the 1979 review had a profound effect on many mobile radio users in the UK. The radio spectrum that the utilities and emergency services had been using was to be reallocated to radio broadcasting. The JRC had a difficult negotiation with the DTI (then responsible for UK spectrum) to secure an alternative frequency band for their members' systems; this new band is known as the 'JRC Band'. A key result of the JRC R&D Sub-Committee was the development of a national frequency plan for this new band, and the mobile radio systems currently being installed by the Gas and Electricity Industries use radio channels allocated under this plan.

3. Channel Congestion

Through the 1970's steadily increasing use of the radio channels led to congestion at times through the day. There was a recognition by the Communications and Instrumentation

Department that the British Gas use of mobile radio was running ahead of the developments by the traditional suppliers, and that there was also a gap in the understanding on how to characterise the behaviour of mobile radio systems in operation.

The early investigation into the problems associated with mobile radio conveniently split into two lines of enquiry. The first of these, known as traffic analysis, was to characterise the important parameters of the calls that were carried. This would make it possible to predict the queues and delays that would occur under specific traffic load conditions. This approach had much in common with that in use for conventional telephony. In telephony, physical wires represent the constraining resource, whilst for mobile systems it is the available radio channels. The sizing of a telephone exchange and the associated circuits connecting it to the public network routinely used traffic parameters, and yielded systems having predictable performance. The aim was to bring the level of understanding for mobile systems up to a similar level. The results of this initiative are to be found today, where it is standard practice for the data traffic associated with proposed business applications to evaluated, so that the grade of service required can be reconciled with the mobile radio resources.

The second area was concerned with measures which would improve the message carrying capacity of the mobile radio network. This area of work represents a theme which has unified successive investigations and developments carried out for the Company. It is an issue which is particularly pressing owing to the number of radio channels being limited. The competition for radio spectrum has been fierce for many years. This exists between users of a particular service, for example mobile radio. The competition also extends to users of services requiring similar frequency bands, such as broadcasting, aeronautical and mobile. The scarcity of the radio spectrum resource has been instrumental in driving the search for methods that increase the capacity of available radio channels.

In early 1977, the techniques for improving the call capacity of the available radio channels were classed into short, medium and longer term measures, and these will be discussed in later sections. It is interesting to look back at these lists from 1992, and see that we are now using the main constituent of the 'longer term' list, namely higher speed data. Current R&T activity in this area is directed at data speeds which are 20 to 30 times the rate speculated at in 1977 though.

Figure 1 summarises some of the key radio spectrum conservation issues with which Communications Section has been concerned. The next two sections will give a closer look at some of the other important outputs of the section, and the staff who strove for the successful results.

4. The Impact of Digital Techniques

During 1978 and 1979 work was directed at the management of mobile radio networks, and was carried out by Mike Weale, who joined the Section from the East Midlands C&I Department. This was a notable development in that it represented the first use of true data transmission across a mobile radio network. The system was able to call a mobile by means of a digital 'address', using less than one second of air time. In the reverse direction, a mobile was able to signify the need to call without the long waits for a channel to become free, which were unfortunately the norm on a congested network. Moreover, the order of arrival of calls was known, so a queue could be presented to the dispatcher for action. In addition to the saving of air time by the use of the very short data bursts, the general level of discipline in the use of radio was improved, which also made more air time available for the actual messages. Co-operation with East Midlands Region led to the procurement of an operational control system, which was installed in the Sheffield district. This operated until recently when the Regional radio system was replaced at the time of the vacation of the old band, and the move to the JRC Band.

The significant development which followed on from the computer controlled management systems was the ability to support data transmissions at higher speeds. From a technology sense, this was a natural progression. The drive towards this goal was fuelled by two, almost independent factors. One of these was the need to continue to improve the capacity of the radio channels. The second factor which emerged in the middle '80s was the automation of the users operations, by the use of computers at the district offices. It was realised that the efficiency of operations would be enhanced if the person carrying out the job was able to give status updates at key times of the activity, and also to send back to the system detail of the work carried out. Ken Drew, who was promoted to lead the section following Mike's move to the C&I Department in Scotland, led the way in this development. The mobile radio circuit is subject to a number of imperfections, such as ignition noise from nearby vehicles, and fading of the signal, which requires the data to be protected so as to avoid corruption of the content. Significant work led to the ability to transport text messages to mobiles with the necessary level of confidence. Systems were installed in two North Thames districts, and interfaced to the Service Department's same day service computer based systems, for which collaboration with John Robson in Service Development, and George Furness of North Thames helped towards success. These systems were installed in 1987, and Figure 2 shows a vehicle installation in use. As a result of pressure from the users, the systems assumed operational status, and operated until very recently when the Region installed radio systems in the new frequency band.

5. Company Field Systems

The Company Field Systems project was established to ensure that a unified information technology environment was integrated with the new mobile radio systems. Under the auspices of this project a number of national specifications were developed. Of particular importance was the definition of the procedures for ensuring that both sender and recipient of any information followed the same rules for establishing contact, packing the information and dealing with abnormal events. Collectively, these considerations are referred to as the 'protocol'. The specification of the the data transmission protocol, interface matters, and general system structure benefitted from the district data systems in North Thames, and Ken Drew contributed extensively to this. Figure 3 presents an overview of the extension of a conventional mobile radio system to provide the data services.

Following from the inputs to the specification work for the new generation of mobile data system, it was identified that the Company needed to be in a position to ensure that the systems developed and supplied met the requirements. This led to the development of a number of tools which allow the performance of key sub-systems of the mobile data network to be checked in detail. A tool was developed and supplied to the Field Systems Group to test the conformity of relevant parts of the system to the communications protocol. This is used at manufacturers premises when system acceptance tests are undertaken.

Tools have been developed to ensure that the performance of the mobile data network meets that required, when the full traffic load is applied. One tool is able to measure the radio signal strength, and correlate this with location whilst the systems are in normal operation. This will allow Regional C&I Departments to be confident that the basic engineering of the radio aspects are correct. The tool has been extended to carry out data quality checks, and again these can be related to location. This is allowing confidence to be built up that the total system will behave as expected when the full load is applied.

One characteristic of much of the communications work carried out at ERS is that it has been seen to be ahead of the developments carried out by the mobile radio industry in general. The traditional suppliers tend to be conservative, and appear, in general, to be demand led. Until 2 or 3 years ago mobile radio was not regarded as a 'respectable' niche of communications. However, with the advent of public cellular systems, and the developments promoted by the European Community for a digital pan-European public system which is just being launched, the work of the communications section now finds itself in the mainstream. This is a pleasing and fitting stage to have reached at this time, when reviewing the history of ERS.

Mobile Data system installed in a North Thames vehicle.