THE DESIGN AND CONSTRUCTION OF THE WARRINGTON COMPRESSOR STATION

PREFACE

Getting gas to customers is more complex than most people know. Gas is put into high pressure pipelines at coastal gas terminals either from the rocks under the sea or from liquified natural gas plants which source their gas from many countries. Once the gas gets into the pipelines its pressure drops depending on volumes and distance. In order to restore the pressure, there are gas compressors throughout the country to make sure that gas customers can receive gas when they need it.

If you went into the national control centre for gas you would see that turning compressors on and off is a key element in maintaining gas supplies. Indeed, the configuration of compressors can be changed when the weather changes to alter the destination of gas.

This paper describes just one compressor project in terms of engineering, project management and internal management processes.

Warrington was the sixteenth Compressor Station on the British Gas National Transmission System and was one of a new generation of designs embodying full remote control facilities for machinery equipment and plant. Completed on time to a tight programme and within budget, the multi million pound station was brought on stream for commercial operation during the winter of 1985/86.

Located on the 42 inch diameter west coast feeder, Warrington is a two unit station, designed to boost the transmission of Frigg and Morecambe gas supplies to the south and south west of the country. The two 29,000 horsepower RB211-driven compressors are each capable of delivering over 1500 million cubic feet of gas a day. Each unit comprises an industrial version of the Rolls Royce RB211 aircraft engine, converting its jet energy into rotational power by means of a Cooper Energy Services RT56 turbine which in turn drives the RF 30 centrifugal compressor. Machinery trains are housed within a reinforced concrete enclosure with sound attenuated air filtration and exhaust systems for the gas turbines.

1) THE ENGINEERING PLANNING REQUIREMENT FOR WARRINGTON COMPRESSOR STATION

1.1. **The five-year planning process within the British Gas Corporation**

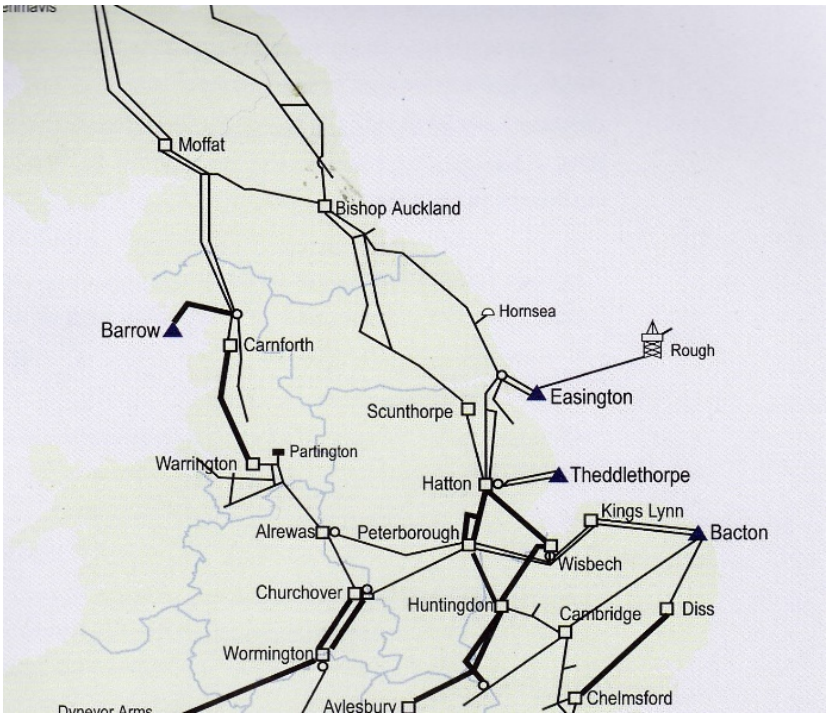
Each year back in the 1970s a rolling five-year plan was produced which outlined the medium-to long term strategies for gas purchasing, marketing, engineering, R & D, personnel, and finance. This was based on forecasts presented by the planning departments in the 12 regions, and at HQ, who examined their gas supply and demand situation for the present and the future. The current and future contracts for the supply of gas were also evaluated, together with the Corporation's own storage and distribution facilities. UK economic activity and the energy market in general were also taken into account, and with financial targets and other constraints upon the corporation were all brought together in the five year plan.

As a result of this, in May 1979 the Executive Committee gave approval in principle to the development of the Morecambe gas field and the associated shore terminal and pipelines. Following this approval, a paper was presented to the Executive in June 1979 to obtain approval for the onshore transmission system, and in particular the transmission of Morecambe Bay gas down the west coast of England.

All of these factors changed from time to time thereby requiring frequent reviews, especially when decisions were taken on individual projects.

It can be seen that a lot of work was carried out prior to papers being put before the directorate.

1.2. **The need**



The Northern section of the National Transmission System

Barrow terminal is the point where Morecambe Bay gas comes ashore. The pipeline leaving the terminal had to follow a land route as it was not possible to lay a pipeline across Morecambe Bay. Because of its high nitrogen content the gas had to be mixed with supplies from another source to bring the specification within British Gas limits before it could be fed to any customer. When Morecambe Bay gas was introduced, the supplies into the Northwest Region exceeded the local demand and provision had to be made to transfer the excess gas to Warburton, whence the existing system could move gas into the Midlands. The output rate from Morecambe field was planned at the time to reach 900 Mcfd although the possibility of higher rates could be expected after further development. The transmission system therefore was designed so that Morecambe gas would mix with Northern Basin gas at Lupton. A 1050mm diameter pipeline would then take the gas south to Warburton, where a compressor station would be required to carry the gas flow into the existing 900mm dia. feeder.

Various options were also considered in respect of the pipeline size and route, including a 900mm dia. pipe instead of 1050mm dia. However, at planned higher flows in later years the 900mm dia. pipe would not be able to cope. The 1050mm dia. pipe route was planned to run from Lupton to Claughton. From Claughton there were two alternatives

a) direct route, via Samlesbury and Blackrod, which was restricted to 612 psi by IGE/TD/1 between Blackrod and Warburton
b) a less direct route which could operate at 1000 psi over the whole route.

Although the higher-pressure route had higher pipeline cost, because of the extra distance, the cost of fuel to operate a compressor station in the long term was lower than operating at a lower pressure. This route was also considered to be more suitable should the Morecambe output increase.

2) **PROJECT TIMING**

The timing of the Lupton to Warburton Link was related to the build-up of new supplies in the north as a whole, not just Morecambe Bay gas. This is because the whole of the West Coast pipeline development had been sized, not only to allow the transmission of Morecambe Bay gas but also substantial quantities of gas from St. Fergus, primarily for mixing purposes, but also allowing the through transmission of St. Fergus gas further south. This allowed reinforcement of the existing East Coast route to be delayed with consequent savings in investment costs. It was on this basis that the original October 1983 completion date was planned. Due to delays in the completion of offshore plant by the supply companies serving the St. Fergus terminal, a slower build-up of these gas supplies was forecast. This meant that the capacity provided by the West Coast development, including the Lupton-Warburton link, would not be required until October 1984 winter, in which the first supplies of Morecambe Bay gas were expected, delaying capital investment, and making significant investment savings.

3) **SITE LOCATION**

3.1 During the early investigations that were carried out by the Environmental Planning Department, the search area concentrated on sites near the Carrington-Partington Petrochemical Complex. The compressor station was to be called Warburton. However, the directorate instructed that these areas should not be considered further due to pipeline connection costs which were not considered acceptable.

3.2 Engineering Planning then came up with a new optimum site search area, ten miles long, in which any point was considered to be suitable economically. The search area was established, after studies had been carried out to determine suitable locations, in conjunction with the Transmission Planning Department. These studies took account of the operating cost of the compressor station, together with the amount of gas to be transmitted, and the pressures at the station inlet.

3.3 The first notice that the Environmental Planning Department would receive was the issue of a planning data sheet, which provided details of the operational requirements of the station. This data sheet was also given to the Construction Department as the basis of the first brief for discussion about a compressor station. The pipeline route having already been established, the preferred search areas on the pipeline were advised by the Transmission Planning Department. The task of the Environmental Planning Department was to find a site that would meet as far as possible a wide range of technical and Town Planning criteria, cause the least disturbance to the area, obtain planning consent from the Local Authority, (avoiding a Public Inquiry and any erroneous planning conditions) and that did not use Grade I agricultural land (since this would also involve a Public Inquiry). Ordnance Survey maps were consulted, to determine the suitability of the local area, then visits were made to obtain local knowledge that is not evident from maps. Detailed information was built up and put on to a map showing areas specific interest.

Site access was examined to see what problems would be met not only in constructing a Compressor Station, but to see if new roads to the site would be required, all of which would determine the site suitability in cost and environmental terms.

The Environmental Planning Department arranged for aerial and topographic surveys to be carried out, with photographs being taken of likely selected sites for discussion. An agent who had local knowledge was employed in conjunction with BGC Legal Department to act on behalf of the Corporation, in dealing with land owners to negotiate the purchase of a site.

3.4. During these early stages the Construction Department was given notice of the need for the Compressor Station again by the issue of a planning data sheet. The Construction Department did not however become involved in the detailed search for the site, which was left to the Environmental Planning Department. However, when the search had narrowed the possible sites to a selected few, the Construction Department became involved, so that costings could be estimated in respect of road access and any constructional problems that would make the site unsuitable. Possible layouts were imposed on the sites to see what problems might arise, together with very rough costings. These exercises helped to determine the most suitable site.

All of this work was carried out under the direction of the Engineering Planning Department as it was their project until permission was given to build from the Directorate.

From these studies one or more sites were chosen, the Environmental Planning Department along with their agent investigated the site owners, and determined the site with the most potential in terms of cost and willingness to sell.

The site (approximately 43.05 acres) was owned by a local man. It was bounded by a road to the east, and a wood to the west. To the north of the site was a small fishing lake owned by a local company which owned several sites in the area for dumping waste. To the south of the site the land had been subjected to infill operations. There were two properties close to the proposed site boundary, one to the south and one to the north. Approximately in the centre of the site there were two cottages that were occupied, one cottage by a small family, and the other by an elderly spinster. Both cottages were in a very poor state of repair without any services.

The Corporation negotiated to purchase the site with vacant possession of these cottages, by agreement. The Local Authority was attempting to rehouse the occupants of the cottages since a demolition order had been made by them.

I have mentioned the above properties and occupants as they feature later in the paper, and had a direct effect on the project.

3.5. Now that the site had been chosen, detailed plot plans could be drawn with details of pipework and roads laid out. The buildings could be positioned and discussions took place with the Plant Operations Department (P.O.D.).

4) **THE STATION DESIGN**

4.1. As noted earlier, discussions in 1978/9 covered a possible Compressor Station called Warburton. From these early discussions Process Flow Diagrams and Engineering Line Diagrams had been produced. The PFD's and ELD's were based on previous station design, such as those at Wisbech and Aylesbury with alterations to suit the process requirements of the Planning Data Sheet for Warrington. Site layouts used at these previous stations for pipework and buildings were also used in the initial site layouts. During later discussion agreement was obtained with Plant Operations Department to change the road design so that road access was only required to the front and sides of the Compressor cabs. It was agreed that by sensible plant design all major items that might need the use of a crane or other such vehicles at a later date could gain access from the proposed road layout. The layout of the compressor cabs and control building provided a site layout that was acceptable to P.O.D. and included the demolition of Wood Cottages.

4.2. While the preliminary studies were being carried out, the Corporation's surveyors carried out an intensive survey of the topography of the proposed site. The survey detailed the site levels, the pattern of the ditches around the site, and the direction of water flow. The areas immediately to the north and south of site were also surveyed. The information obtained gave an indication of the type of trees in the area, and the contours of the adjoining land. This information enabled landscaping proposals to be prepared, and the site survey was used by the Design Department. The survey was also used at a later date as a reference for a site investigation.

4. 3. All of these preliminary studies were carried out with the agreement of the Engineering Planning Department. Agreement having been obtained on preliminary layouts, the Design Department were able to provide piping layouts and possible foundation requirements. A site survey was necessary, and during 1980 a contract was placed to carry out this work. The scope of work covered the drilling of 8 boreholes to depths of between 9.7m and 12.7m using the "Shell and Auger" method. Undisturbed samples were recovered and standard penetration tests were performed at approximately lm intervals in each borehole.

In order to monitor groundwater conditions piezometers were installed in 4 of the 8 boreholes, and a standpipe was installed in a fifth borehole, to enable water level readings to be taken.

Additionally, 25 trial pits were dug, using a J.C.B. 807 tracked excavator. The trial pits were dug at positions between the boreholes on the sites of proposed structures, and pipe areas, and along the lines of new roads and contractors' working areas. A further contract was awarded to monitor the site investigation work. The results were then analysed to produce a Geotechnical Report. This report detailed the findings of the site investigations, and made recommendations for the design of the earthworks, site drainage, and foundations in relation to the proposed site layout

4.4 The findings of the Report confirmed that previously used methods of construction were acceptable at Warrington in respect of the compressor cab, and control building foundation. Previous designs for road construction were also acceptable.

The west of the site was covered with a layer of peat up to depths of 2m, and the groundwater was shown to be constant at 3m below ground level. The recommendation that the peat should be removed before major work started was accepted, and this work formed part of the first contract.

The boulder clay encountered on the site was considered suitable for backfill provided the moisture content did not exceed 20% at the time of placing.

4.5. The buildings proposed in the early stages of the project were a repeat of the buildings that had been previously used at Aylesbury and Wisbech Compressor Stations and were known as the standard design. The exception was the finish. Aylesbury and Wisbech had a painted exterior, and ceramic tile finish respectively. It was intended to finish Warrington in ceramic tiles. The geotechnical report from Ove Arup confirmed that the proposed compressor cabs used at the last two stations could be repeated, using driven cast in situ piles for the foundations, as used at Aylesbury and Wisbech. The compressor cab design that was to be used at Warrington, was essentially an acoustic housing for a compressor unit with ancillary equipment, sized to accommodate machinery of all approved manufacturers. The foundations were designed with all service ducts to accommodate all cabling and pipework.

The construction of the compressor cab was an internal steel frame supporting a cast reinforced concrete wall, and roof. A snow hood was designed to be cast in concrete over the air intake after the machinery and ventilation equipment is installed.

4.6. The standard control building housed control equipment, operating administrative personnel, workshops and utility rooms. The standard allowed flexibility in the accommodation such that size of individual components could be varied dependent upon the requirements of the specific station. The control building standard was a steel frame with reinforced cast in situ construction with a tile or paint finish.

4.7. Other buildings were required to house a standby generator, and separately an oil and paint store. A compound was also required to house a 11 KVA transformer. All of these buildings fitted into what had come to be known as the standard layout. Additionally, at Warrington a separate building was required at the request of North West Electricity to house a supply metering unit, and isolator since the site was designed for remote operation and was not permanently staffed.

4.8. **Building Design Changes**

4.8.1. All of the designs for the buildings that were to be based at Warrington were considered to be the Standard. However, studies were being undertaken by a standardisation working party within the Construction Department, but not as part of the Warrington project, to determine if the previous methods of construction could be improved. The changes examined were to establish if a cost saving in construction could be made, and to see if the construction period could be reduced.

The standard building already had precast concrete which had been painted, and had tiles fixed to the exterior. Painted finish, it was considered, would cause long term maintenance problems, and would be unattractive as the finish deteriorated. A good quality exposed aggregate finish was examined but the cost in achieving a good finish was unacceptable. Profiled cladding on a steel frame presented a good finish but required special acoustic treatment. It was also considered that the cladding could be susceptible to mechanical damage.

4.8.2. An alternative which was finally accepted was a brick exterior, which lent itself to a cavity construction, and also provided better weathering of the exterior walls. It was also estimated that savings in costs could be achieved with brickwork, as the in situ concrete on the cab could be thinner than that used at previous sites. Also, the control building, although requiring a steel frame, could be built of a blockwork inner wall, with a cavity and brick outer wall which was a more conventional building method.

4. 8. 3. The compressor cab snow hood in the past had been erected after the installation of the compressor equipment, and was constructed of concrete, this meant that the building contractor would have to remain on site after completion of his other work, to complete the snow hood.

The snow hood was changed to a steel frame bolted on to the cab structure after the machinery equipment was installed, but was erected by the machinery contractor, who was responsible for the cladding around the exhaust stack and fitting of all doors to the cab which were acoustically treated.

4.8.4. AII other buildings on the site were also given a brick exterior to match the control building and compressor cabs. Studies were also undertaken during this time by the Project Planning Department to produce not only a “standard” building but a “standard” programme which could be used as a basis for the project programme and could form part of the construction programme.

Programmes were produced which examined different methods of construction, including the possibility of using standard blockwork on the compressor cab wall instead of concrete. Although the programme produced saved 25 days, the idea was not progressed.

4.9. Standby Generator (S.B.G)

4.9.1. The original station design called for a gas-driven 500 KVA standby generator. The S.B.G. was to be housed in a purpose-built building that would be acoustically treated to contain noise. All services into the building were via ducts. The S.B.G. would sit over concrete trenches which would allow ease of installation of the cables and other services.

4.9.2. Proposals were put forward that saved considerable costs and construction time. A proposal to change from a gas-driven S.B.G. to a diesel unit, housed in a purpose made acoustically clad steel enclosure was not readily accepted, as all compressor stations built in the previous few years were built using a gas-driven unit. The proposal was for a 500 KVA unit, with fuel storage for 24 hours, in which time it was felt that any emergency would have been dealt with, including total failure of the electricity supply. After considerable discussion it was finally agreed that fuel storage for 72 hours running would be provided.

The size of the enclosure also came in for close scrutiny. The original intention had been that for maintenance purposes there would be removable panels on the side of the enclosure. This was not acceptable to P.O.D. who wished to be able to carry out routine maintenance under cover. The size of the enclosure was therefore increased to allow a working space around the S.B.G. of 1.2m at the narrowest area. The enclosure was designed to be removed in the event that there would be a need to remove a major part of the equipment for repair.

The fuel was fed from the storage tank by gravity, feeding a day tank situated at the base of the unit. The enclosure was fitted with fire detection and protection equipment as was the gas fired unit.

4.9 .3. Although the S.B.G. was to be driven by diesel, P.O.D. insisted that provision be made for a gas supply to be made available, so that in the event of a mobile standby unit being brought to site it could be used while repair or maintenance work was carried out on the permanent unit. Although P.O.D. had both gas and diesel driven mobile units no guarantee could be given that a diesel unit could be supplied to Warrington. There were therefore connections for supply of gas and diesel in the event that another unit is brought to the site.

4.10. The Mechanical Design

4.10.1 In November 1980 the Process Flow Diagrams (P.F.Ds) and Engineering Line Diagrams (E.L.Ds) based on previous stations were issued which detailed the sizes of the pipework, the operating pressures and temperature. The main station inlet pipework was established as I050 mm dia. inlet, with 900 mm outlet. The station pipework was connected to the national grid pipeline by a series of valves, which could isolate the station from the grid and were controlled remotely by the operational centre. The design operating flow was set as a maximum 60 x 10^6/(ST)m^3/d. with a maximum operating pressure of 70 Bar at 30ºC. (1,030 psi) The maximum design operating outlet pressure and flow were the same as the inlet, with an increase of the operating temperature to 50ºC. The station design included 3 gas scrubbers. The main station process pipework with both inlet and outlet to the compressors was to be directly buried or placed in concrete trenches. The pipework in the concrete trenches was also to be acoustically lagged.

The burial of the pipework. Placing it in trenches with acoustic lagging, was a recommendation of the Environmental Planning & Machinery Departments to reduce the operating noise of the station. If the previous station design had been followed, the process pipework would have been above ground. However, because of the close proximity of two properties, one to the north east of the site (Oaktree Cottage) and the Mission House to the south east of the site, special treatment was advised. Proposals had been put forward by the Environmental Planning Department to purchase these two properties, and thus save construction costs associated with reducing the operating noise of the station. This recommendation was however not accepted by the Directorate.

4.10.2. The PFDs and ELDs covered the operating requirements of the station and detailed the various equipment required along with the instrumentation required to monitor and control the station's operation. The PF’s and ELDs covered the following major items: -

a) PROCESS FLOW

b) GAS SCRUBBERS and CONDENSATE TANK

c) PRESSURE REDUCTION UNIT

d) ACTUATING GAS and MAIN SERVICES

e) GAS COMPRESSION

f) VENTING

and other items such as lubricating oil lines, water services and fuel gas for the gas generator.

4.10.3. The gas scrubbers were to be placed on site in the required location ready to be included in the station pipework by the main works contractor.

The function of the gas scrubbers was to remove from the gas stream any contamination that would damage the compressor equipment, such as solid objects, and liquids. Solid objects were deposited in the base of the scrubber vessel, as were liquids.

The early design of the station called for 3 scrubbers, but in April 1982 the P.E.Ds were revised to include only 2 scrubbers with the scrubber design capacity changed to make each scrubber capable of taking one half of the maximum station flow. The scrubbers were designed with an auto dump system to automatically remove liquids (condensate) from the scrubbers and pass them into the condensate tank. The condensate tank was sized at $45m^3$ to accommodate I0,000 gallons of condensate, and would have a blanket gas within the condensate tank.

In October 1982 several changes were made to the design proposals which at this time formed part of the agreed station design philosophy, and were the subject of tender evaluation with companies who had tendered to design, manufacture and supply the gas scrubbers, and condensate tanks, together with the auto dump system.

The changes proposed were: -

a) Delete the auto dump system, in lieu of a manual system.

b) Delete the blanket gas system from the condensate tank, the tank to be continuously vented to atmosphere.

c) Reduction in the size of the condensate tank capacity and size from $45m^3$ to $15m^3$ (3000 gallons) tank.

d) Reduce condensate tank specification from BS 5500 category 1 to category 3.

These proposals were made to reduce the cost of the scrubber system, as there was evidence that the quantities of liquid that could be expected at Warrington were less than those first expected. The scrubbers and condensate tank system were to the Machinery Department Specification MDS/I7. The specification MDS/I7 was prepared for all compressor stations, which determined the size for the condensate tank.

Since the first compressor was commissioned in 1970 the quantities of liquids collected were generally less than expected. Liquids such as oil, water, glycol, methanol and hydrates of small quantities had been found in the scrubber and condensate tanks at most of the compressor stations. The amounts collected did not interfere with compressor operations.

The gas at Warrington would have passed through 4 sets of scrubbing facilities when transmitted from Scotland.

The gas transmitted from Barrow had adequate specification to remove hydrocarbons by the chilling processes. The chilling process ensured that gas would not have a hydrocarbon dewpoint greater than -1°C at any pressure. The worst predicted dewpoint was -9°C However, there was a low probability that failure of the liquid separation system could result in some liquid carry-over, but these liquids would be reabsorbed into the gas stream. It was expected that the major source of liquid was likely to be the result of maintenance and testing on the pipeline itself.

As part of the overall change, the condensate construction design standard was reduced from BS 5500 category I to category 3, as it was felt that the design conditions stated in MDS/I7 were acceptable for a category 3 tank. (Design standards – Design Pressure 3.5 bar for a temperature range of $-l^0$C to + 50°C and to withstand full vacuum conditions). The effect of the change was that welding of the tank seams was only required to be carried out from one side, i.e. welding could be carried out from the outside of the vessel. Category 1 called for welding to be carried out both inside and outside the vessel. The effect of this change was that costs for manufacture could be reduced. Although this change was accepted, and the manufacturers of the condensate tank advised of this change, the mechanical design department objected, the manufacturer therefore had to comply with category 1.

Because of the low volumes of liquid expected to be retained in the gas scrubber it was felt that the need for an auto dump for the removal of condensate from the scrubber was not necessary. A manual dump was therefore accepted which saved approximately £I0,000 in equipment not required.

Condensates were only collected and taken off site by P.O.D. if unavoidable. They had no resale value, involved Customs & Excise duties, and their disposal by any other method than evaporation resulted in a revenue loss to B.G.C. It was also understood that setting up the instrumentation on a blanket gas system was troublesome and as such, in some stations, the tanks were vented to atmosphere. Some maintenance savings would thus result by deletion of the system. This further change was accepted with a saving of approximately £8,000.

The above changes were made in the early days of the contract to design and manufacture the scrubber and condensate system, and did not therefore affect the manufacture and delivery. Savings of £26,000 were made.

4.11 The pressure reduction unit was of a similar design to that used at previous stations. It could be seen from the P.F.D. that all essential gas services and equipment were supplied with gas at the correct flow and pressure to operate valve actuating supply fuel gas to the gas generators, and domestic gas to the control building.

4.12 The venting system was an important part of the station safety system. In the event of an emergency shut down the main process pipework and compressor units were vented to atmosphere via the vent stack. The rate of flow to the vent stack was controlled by a quiet vent unit which restricted the gas flow to 7.75 Kg/sec.

4.13. The water supplies

4.2.1. The water supply to the compressor station posed a particular problem as the water pressure in the area was restricted because of low pressure caused by a poor distribution system. The normal station design would be to have a fire water reservoir of 31,000 gallons, but because of the poor supply the firewater reservoir was increased to 80,000. Also, to the north of the site was a small pond. The fire authority suggested that it would be helpful to have the facility of being able to use the pond to assist in charging the site fire ring main. The fire ring main therefore was designed so that the Fire Brigade could not only charge the fire ring main from the fire reservoir, using the pump on their fire tenders, but could also place hoses in the pond and connect on to fire main at a charging manifold to the north of the site, again using the fire tender pump to draw the water from the pond.

5) **COSTING, PLANNING AND CONTROL OF THE PROJECT**

5.1. As noted earlier in the paper the costing and programming of the project before project approval was controlled by the Engineering Planning Department. Before permission was given by the directorate to start formal design, placing of tender enquiries for both free issue materials, and contractors to carry out the construction work, an overall project time table had to be agreed, together with costs for the proposed project.

A small project team in the construction department examined costs of past projects, where work was similar, to obtain cost estimates for Warrington. Also, a firm of Quantity Surveyors were appointed who had a good knowledge of the work proposed, to assist in the costing exercise. At this time full detailed design drawings had not been produced, however site layouts detailed the approximate pipe routes, and building layout. With this information and using detailed knowledge of past projects it was possible to cost the proposed station.

5.2. To obtain project approval a paper detailing the estimated costs had to be presented to the Special Expenditure Committee, (S.E.C.), and also defined the construction period. An operational date of October 1984 had already been defined during the Engineering Planning Department's work on defining the need for Warrington. From the programme planning exercise detailing the contract strategy, design requirements, lead time to purchase free issue materials, and time required to tender and place contracts, a date was established, for the presentation of the paper to the S.E.C. The S.E.C. paper was presented and approved in September 1981, at which point the project becomes the responsibility of the Construction Department.

A Project Manager and Project Engineers who were working to take the Project to the S.E.C. took over. The Project Manager was responsible for the overall project, the Project Engineers were responsible for one or more contracts, acting as The Engineer's representative under the Contract conditions, with a resident Site Manager also appointed to act as The Engineer's representative, but only with responsibility for the day to day running of the site. The Project Engineer was responsible for the control and administration of the Contract. The person appointed to be the Engineer was the departmental head of Compressor group in the Construction Department.

5.3. Because of the time required to manufacture and deliver the two R8211 gas generators, agreement had been obtained for the advance purchase of the RB211s from Rolls Royce in October 1981. Also, during the preparation of the S.E.C. paper, preparations were well in hand with Tender enquiry documents for the machinery contract. Tender documents were issued in October 1981 for the machinery contract, with the provision that the successful Contractor should take over the RB211 order with Rolls Royce from the Corporation.

5.4. At the inception of Warrington, the Construction Department was in the process of starting to use a new “Project Management Cost Control and Information System” called PROMIS. The object of the PROMIS system was to be able to have a better understanding and control of the expenditure of a project, together with the programme.

The costs were broken down into Work Packages, which were then broken down into Elements. The whole of the project cost was then categorised with individual W.Ps and Es being given unique numbers which were retained until the end of the project. At a later stage when the major contracts were awarded, the contractor also used these unique WPE numbers, which were against the various items of work in the Contract Bill of Quantities.

As the contracts, and the project, progressed, each month a computer printout was produced which detailed expenditure although, because of the reporting system, the expenditure on the printout could be two months late.

5. 5. The PROMIS system had been in use for three years on the Warrington project and a little longer in the department as a whole. The system also covered the Purchasing Department, who were only allowed to place orders for materials against agreed approved costs controlled by the Project Manager. If changes were required in expenditure or programme, a Change Impact Document (C.I.D) had to be raised. Agreement could only be given to a change once a signature of the appropriate level commensurate with the value of the change had been agreed. This could sometimes mean that a signature by a director was required. Delays could occur, which at times was not satisfactory when the progress of a Contract could be affected.

5.6. As discussed earlier, a programme was produced which detailed the strategy, project and contract start and completion dates and interfaces with departments such as design and purchasing. A critical path network was produced by the Transmission Planning Department under the direction of the Project Manager and Engineers. Each department that had an input agreed the programme together with the relevant durations for work and interfaces. If at a later date changes were requested a C.I.D. might be produced to allow the change, as the project network was also tied into PROMIS. Again, each month a computer report was produced, which detailed the activities and highlighted delays. This allowed the appropriate department to take action if activities were late, to bring the activity causing lateness back on time.

Each month all departments with an input were required to state if the future programmed work for the next eight weeks was on time, or detail revised dates if the activity was to be late. The information was collated, and examined to see what effect, if any, lateness of an activity would have on other areas, and the project as a whole.

If the project end date was thrown out, it was added to a special report sent to the directorate.

5.7. Each major contractor was required under the Contract to produce a programme, breaking down the work into areas that matched the PROMIS cost codes. Some Contractors carried this out without problems, others had found this difficult or were unable to do so. This information was to be produced in computer form, providing I.J. listings, precedence activities, and histograms, which were to be updated each month. The amount of information produced was dependent on the Contractor. Each month the Contractor had to provide 8 week forward looking bar charts, and two-week bar charts so that progress could be monitored, and where appropriate, action taken. However, the programme was the responsibility of the Contractor. Action could only be requested. If the Contractor did not take notice of requests to take remedial action, or if the Contract ran late because of his own actions, the Contract would be brought to bear on the Contractor, by formal notice of his contractual obligations.

6) **THE CONSTRUCTION PHASE**

6.1. The Environmental Planning Department lodged a detailed Planning Application with Warrington Borough Council in early November 1981. It was expected to be considered at the Council's Planning Meeting in mid-January 1982. The application included the demolition of Wood Cottage, which had already been the subject of discussion with the Local Authority.

At the time of the Planning Application, the site had been purchased but without vacant possession of the cottage. The Corporation did not have access to the whole site because the occupant had not vacated the cottage as promised. The Environmental Planning and Legal Departments took measures to obtain vacant possession of the property. The cottages were not considered to be habitable and a demolition order had been served by the Local Authority.

It was expected that the Corporation would have possession in May/June 1982. The effect of was that the preliminary Civil Works Contract for site clearance would be delayed by one to two months.

6.2. It will be seen from the foregoing that in September 1981 a detailed programme had been produced. Also contract strategy had been determined, and a design brief produced. It was planned that there would be four major contracts, which would be: -

a) Preliminary Civil Works, for site clearance, temporary road, permanent access road, provision of BGC site accommodation.

b) Building and Civil Works Contract - which would include piling, cab, and control building foundations, the building and site roads and part drainage, part security fence.

c) Main Contract which included the pipework, instrumentation, complete security fence, final drainage, ducts, electrical work, lighting etc.

d) Machinery Contract which included the design, manufacture and installation of the compressor train, the ventilation system and controls.

There were also two other small contracts for the design and supply of fire and gas detection equipment. All of this was essential to be able to determine costs and programmes. Design work for the site clearance had been easy to establish with the preliminary works contract and the Tender documentation, but the Design Department were not able to commit full design resources until S.E.C. approval had been obtained.

6.3. Planning permission was received for the compressor station. However, the Demolition Order raised by the Local Authority was found to be unenforceable with the result that the occupant of Wood Cottage had the right to continue in residence. Although the 1981/2 winter was severe, she did not wish to move since she had lived in the cottage all her life and was content to continue to live there.

Further attempts to obtain and enforce a new Demolition Order and evict the occupant failed in the Courts.

This meant that the station layout could not be built because access could not be gained to demolish Wood Cottage.

To maintain the project end date, despite these delays and the change in layout required, drastic measures were called for. It was decided that the only way the station could be built and also retain Wood Cottage, was to move the whole of the station west on the site and reduce the station area. The station layout was moved and condensed. It also meant that the Preliminary Civil Contract Tenders which had been returned by this time could not be considered.

6.4. As stated earlier, the buildings were of similar design to previous stations, however because there was to be a major change, i.e. brick exterior, the drawings were not in sufficient detail for Tender enquiry. The compressor cab and control building foundation details were available, as they were the same as those used at previous stations.

A complete Tender package was issued in the beginning of JuIy 1982 which included not only the site clearance and provision of Contractors compound, and site roads, but also included the piling and foundations for the cabs and control buildings. This change meant that the design work on the buildings could be completed. The Contract strategy changed with the scope of the first two Contractors changing. During this time the occupier of Wood Cottage had a fall and was taken to hospital. The Corporation, however, could not demolish the cottage since it was under a 1egal obligation to ensure that she could return to live in Wood Cottage at any time. This would have meant that she would have lived for at least 2½ years in the middle of a construction site, and thence next to an operational compressor station.

6.5 The Bases Contract, as the first contract was now known, was awarded at the end of August 1982, some four months after the original intended start date of the first contract. It also meant that major site clearance and civil work would be carried out in the winter months, with the obvious problems with site conditions. The bases contract was completed to programme at the beginning of April 1983.

Tenders were issued for the Building and civil contract at the beginning of November 1982 with the contract being awarded at the beginning of March 1993. The Building and civil contract was completed in the middle of February 1984.

This contract did not run smoothly however, as the contractor was programmed to finish several areas of work and be clear in other areas before the Main Works Contractor was to have possession. The Main Works contract was awarded at the beginning of August 1983. This meant that the two Contractors would be working on the site. Dates were imposed on both of the contractors for completion of sections of work, and hand-over of areas for work to be progressed. The Building and Civil contractor was not able to meet some of these dates, which caused access problems and disruption to the Main Works contractor.

6.6 The Corporation purchased materials which were free issued to the Main works contractor. The material included all pipes, valves, vessels, and electrical equipment. Some instrumentation equipment was also included, including the station control panel and communications desk.

Before the Corporation placed orders for the materials, dates were agreed with the suppliers that met the project programme. These delivery dates became an integral part of the programme of the Main Works Contractor. In general, most items were delivered on time. The one major item of free issue materials that failed to meet the delivery date was the scrubbers. The delivery date was missed by 7 weeks. The late delivery disrupted the Main Works Contractor's programme as the scrubbers were an integral part of the pipework. An assessment of the delay was made and an extension was awarded to the Contractor.

Because of the delay, the Main Works Contractor's programme was assessed along with the alternatives that were available to the Contractor to mitigate delays. The Main Works Contract had sectional completion dates which allowed access by the pipeline Contractor to tie in the transmission system to the station, and access for the Machinery Contractor to test and commission the machinery. AII of the most important dates were missed, with the effect that disruption had been caused to the machinery Contractor, and the equipment was not handed over to the Corporation at the required date to enable commissioning to start at the correct time.

The machinery Contractor altered his programme several times to take account of the delay caused by the Main Works Contractor.

6.9. The pipeline from Warburton to the site was completed on time to allow gas to be available for commissioning of the station. However, it was not intended that the pipelines from Lupton would be completed at the same time because of programme and other planning considerations that occurred earlier in the project. It was however programmed that the pipeline would be available in September 1984 so that pumping and commissioning tests could take place. The construction of the pipelines has been delayed due to unforeseen problems with peat on the pipe route. It was known that peat areas would have to be passed when laying the pipeline but it was not expected to encounter peat layers of such great depth. The result was that the pipeline commissioning was delayed by almost I0 weeks, which in turn meant that the final station commissioning was not completed until January 1985, with one machine being commissioned late in December 1984.

Wood Cottage was demolished just before the site works completion as sadly the occupant had moved to a care home and died there.

7) COMMISSIONING

7.1 As part of the commissioning process all equipment was checked to ensure correct operation. This included seeing if the scrubbers were working correctly. In this case it meant an internal examination of the vessel.

Each scrubber was isolated for the inspection. Small rubber particles were found that could not be explained and if not dumped by the action of the nozzles used to separate any debris in the gas stream would have caused serious damage to the compressors. The rubber material was very thin and could have been part of an inflatable sphere used to stop water passing a hydrostatic pressure test of new pipe work which would have included the new pipeline connecting the station to the grid There had not been any reports of any such items being left within the new pipework on the compressor station nor from the new connection to the national grid. The scrubbers were cleaned out and recommissioned with no further problems.

7.2 There were complaints about noise from the site due to the close proximity of people living nearby. Although the pipework on site had been put into pits and fitted with acoustic lagging more work was required to reduce the noise.

Concrete covers were fitted over the pits covering the pipework and rubber matting was installed to seal any gaps that might cause noise to escape.

7.3 The exhaust system had sound attenuation fitted but this did not work sufficiently well to control low level noise. The machinery contractor who was responsible for dealing with the nose problems installed a series of loudspeakers around the top of the exhaust stack known as active attenuation which operated automatically when the machinery was in operation.

7.4 In the first 6 months of operation it was found that one of the automatic 36” rotary control valves was passing gas when in the shut position. There was another 36” manually operated valve in line with the faulty valve. These two valves were part of the control of the gas flow from one of the compressor units. The valve was removed by the main contractor under supervision of POD, a member of the project team, a BG QA inspector and a representative of the valve manufacture. At each stage photographs and a record of what was found.

The valve was taken back to the manufacturer’s works in Scotland to be examined. Each phase of the dismantling process was photographed and a note made of what was found.

The rotary valve had a seal that turned in a clockwise direction each time it was closed or opened to ensure that any wear would be uniform in use. It was found that this seal had been cut because it had not fitted correctly in manufacture and should not have passed inspection. The reason why this had happened was not clear.

The manufacturer accepted responsibility for all costs associated with removal and supply and installation of a replacement valve.

Warrington Compressor Station

8) **THE INAUGURATION**

The formal opening of Warrington Compressor station was carried out by Mr James McHugh, the Managing Director of Production and Supply on August 12th, 1988, three years after the compressor station had started operating and problems had been resolved following commissioning.

Members of the Project Team at the Inauguration

Extract from the brochure for the Inauguration of Warrington Compressor Station on Friday 12 August 1988

Considerable attention has been directed towards the environmental impact of the station on the Cheshire Countryside. The concrete compressor enclosures have been treated with an outer cladding of brick which not only blends with the surrounding countryside but also provides a maintenance free additional layer of sound attenuation. Furthermore, when the machinery is in operation an active attenuation system producing anti-noise assists the turbine silencers to further reduce the low frequency exhaust rumble.

The Construction Department of British Gas has been responsible for the design of the installation and for supervising the construction. The station was commissioned and taken over by Plant Operations Department and has been available for grid operation for some time.

Today's Inauguration of Warrington Compressor Station marks another milestone in the successful partnership between the private sector contractors and British Gas, and a tribute is due to the efforts of all those who have taken part in this project.

9) ACKNOWLEDGEMENTS

This paper was written by Charles Smith and is based on a paper submitted to the IGE by him in 1985. Charles was one of the project engineers on the Warrington project, responsible for managing the main works contract, and the compressor and scrubbers manufacturers' contracts, as well as for liaison with other departments to ensure that designs and specifications were issued on time. He had very active support from all of the various design departments from start to end of the project, in particular the machinery engineers and the instrumentation and electrical engineers, who attended all contact discussions with the compressor contractor and reviewed and approved the design drawings. Plant Operations Department were involved in all discussions of all aspects of the design. Towards the end of the project, a contract was let for writing and producing a plant operation and maintenance manual for every item of equipment that was to be used on the site.