Future Trends in Gas Production and Transmission

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Future trends in gas production and transmission

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Increased awareness of environmental factors will heighten the attractiveness of gas as a fuel and the pipeline as a means of delivering energy to the point of use. Demand for gas will be so strong that available supplies will be reserved for premium uses with the result that the design of systems will have to encompass considerable flexibility in load handling.

In addition to imports, new supplies of natural gas will come principally from the deeper waters of the Continental Shelf in the range 200–1000 m and further developments in sub-sea techniques of construction, operation and maintenance will be required. Plants manufacturing natural-gas substitutes from liquid petroleum will be integrated into systems together with large scale storages.

Advances in transmission systems will require better harnessing of known technology rather than a breakthrough into completely new areas of knowledge both in material and equipment. Developments in automatic welding, in-service internal inspection of pipelines and improved data collection and transmission can be expected.

1. Introduction

Within the United Kingdom, the system of gas supply has passed through many evolutionary stages, both technical and organizational, since the first public supply under charter commenced in the early nineteenth century. It has progressed from local distribution on a small scale of unpurified manufactured gas principally for the purposes of illumination to a nationally integrated system of supply under public ownership of a highly refined fuel as a source of heat with virtually no uses as an illuminant. Until a very few years ago, the supply was based upon a hydrogen-rich gas with an energy value of 19.0 MJ/m^3 (500 Btu/ft^3), but with the advent of natural gas from the North Sea the decision was taken to convert the whole country to the direct supply of natural gas at an energy value of a little over 38.0 MJ/m^3 (1000 Btu/ft^3). This process of conversion is now well advanced: by October 1973 over 9½ million premises had been converted, and with the possible exception of one or two isolated pockets where hydrocarbon/air mixtures may still be the basis of supply, all customers will be receiving neat natural gas well before the 1980s.

On the basis of currently contracted reserves of natural gas the U.K. gas industry will be able by the end of this decade to meet 16–17 % of the projected national demand for energy equivalent to approximately 2.1×10^{18} J/annum (5.5×10^9 ft^3/day, 156×10^6 m^3/day). Within this timescale some of the earlier and smaller gasfields to come into production will have started to decline but the introduction of supplies from new fields already under contract will more than make up for the deficiency, resulting in a considerable further growth in the supply system between now and 1980. Depending upon the rate of further discovery and the recovery of associated gas from some offshore oilfields this rate of growth could be exceeded and might well continue beyond the 1980s. There are too many uncertainties to make firm estimates but it is perfectly possible that natural gas will eventually meet up to 20 % of the total energy demand of the country after 1980, say about 2.45×10^{18} J/a. What is certain is that for the whole of the 1980s the characteristics of the supply will be those of natural gas, whether drawn in fact from natural strata or manufactured as a substitute from some carbonaceous raw material.

Since the early 1960s the growth of the gas industry has been rapid. Even during the era of the production of town gas by the steam reforming of naphtha annual increases in load of 10–12 % per annum were recorded regularly; since the introduction of natural gas the rate of annual growth has risen sharply and has touched 30 %. In 1964/65 gas output in Britain was equivalent to 10^9 ft^3/day (28.3×10^6 m^3/day) of natural gas (although the send out was actually of town gas); in the year ended 31 March 1973, it was almost 3×10^9 ft^3/day (84.9×10^6 m^3/day) and the 1967 White Paper target of 4×10^9 ft^3/day (113×10^6 m^3/day) will be met by 1975.

The demand for higher standards of personal comfort in the home, pressure to improve the environment in urban areas under the impetus of the Clean Air Act and a spectacular growth in specialized uses of gas in manufacturing industry have combined to produce this rapid growth. Who can say that these forces are now spent? The 1980s will surely see an acceleration of the social and economic trends of today. Concern for the environment in the widest sense can be expected to grow and legislation against pollution to develop further, automation in industry will increase and man will demand yet higher standards of personal comfort. These trends will combine to maintain a strong demand for natural gas as a convenience fuel, since it is easy to purify, its production leaves no permanent scars on the landscape, it is readily transported in pipelines underground and requires no individual storage at the point of use. It is ash-free, controllable yet flexible in use and the products of combustion, being almost wholly carbon dioxide and water vapour, can be discharged to the atmosphere by a simple flue. The events of recent years and, more particularly, of recent weeks in the Middle East have also served to underline the security value of an indigenous fuel and it seems certain that at competitive prices potential demand could far outstrip supply. In these circumstances available supplies will have to be reserved for the premium uses where resource savings are greatest and this implies that the future supply system has to be designed to accommodate the large seasonal changes in demand which are characteristic of a wholly premium market with its high content of domestic and space-heating load.

A very real problem for the future may be how the selective consumption within industry is to be achieved. Successive governments have seen the need to use the nationalized industries as an economic weapon so that, even in periods of apparently reduced restraint, particular distortions have been imposed upon the pricing structures of some public industries. It would be totally unrealistic to expect that this system is about to change and that the problem of energy allocation is readily soluble by normal market force mechanisms.

2. Sources of gas in the 1980s

Onshore U.K. exploration prospects are not over-encouraging and by the mid-1980s the major prospects on the continental shelf in water depths up to about 150 m should have been explored fully. During the 1980s therefore the major exploration effort will have to be directed to the deeper waters of the continental shelf, say, between 200 and 600 m, or even perhaps as deep as 1000 m. While preliminary exploration of these prospects can be expected to be accomplished by seismic methods closely related to those in use today and, with the addition of dynamic positioning, the larger type of semi-submersible drilling vehicle now coming into use should be capable of accomplishing the drilling, a major change will have to take place in production methods.

(a) *Production of natural gas offshore*

It can be expected that production wells will be completed on the sea-floor with submarine collection and treatment facilities. Much of the equipment needed, such as well-head cellars, separators and control equipment, is already available in commercial prototype form, although designed primarily for the handling of oil, and there will need to be further development of specialist gas handling equipment, such as dehydration units, heaters, etc. All of the sub-sea units will be equipped with remote control and handling devices for routine operations, including well repairs, but have the capability to accept lock-on diving bells so that technicians can descend to the sea-floor to carry out maintenance and deal with the more awkward operational problems of the oil and gas handling equipment in normal atmospheric conditions. Further engineering development will be necessary before current sub-sea systems and procedures could be considered routine, but there is no reason to suppose that normal commercial pressures will be insufficient to ensure completion of all the detailed development work within the next ten years.

Disposal of the oil produced from these deep waters should not present major new problems since it will be possible to establish oil storage tanks on the sea-bed adjacent to the production facilities and loading into tanker at a floating platform can be visualized. Batch loading of gas, however, although technically possible, cannot readily be economic and submarine pipelines will still be required. A major problem to be solved, therefore, is that of how to lay large-diameter gaslines in such water depths: it seems clear that a straightforward scaling-up of conventional floating barge equipment is unlikely to be successful and the answer probably lies in the development of large semi-submersible lay barges, again equipped with full dynamic positioning. Repair of a deep pipeline in case of damage will also have to be thought out, although the likelihood of damage should be reduced in these deep waters once the pipe has been laid.

In the very nature of things, discoveries in very deep water will be a long way from shore and recompression of the gas *en route* will be necessary. Where possible the most likely scheme would seem to be the collection and movement of the gas by submarine pipeline into an area of water depth of around 200 m, where a platform would be installed to carry the gas compression equipment. Such a platform could be expected to consist of a concrete base section in the form of one or more columns surmounted by a steel superstructure housing the machinery. The superstructure would probably take the form of a dumb barge which could be built, equipped and fully tested in a shipyard before being towed out to location and, after the erection, requiring only final pipe connexions to render the package operational. In this way conventional gas-turbine-driven centrifugal compressors could fulfil the compression duty and operation and maintenance of the essential equipment should not present undue difficulty. It has also been suggested that sea-floor compressors will need to be developed, driven either electrically or hydraulically, the power being generated on the surface and fed down through cables or armoured hoses to the sea-floor. By this means the prime movers could be located on a floating or semi-submersible structure and readily accessible for maintenance with the compressors duplicated so that oceanic vehicles could remove them bodily for servicing ashore. Clearly such a system has a number of added complications, not least that of making and breaking the high-pressure gasline joints and keeping the compressor free of seaborne detritus, but in waters too deep to permit fixed platforms to be built, this solution should be feasible. However, ocean structures are developing at such a rate that current depth limitations will not be valid for long and seabed compression may well not be developed within the 1980s.

It has further been suggested that gas might be produced far from shore and then either liquefied on the spot and shipped in cryogenic tankers or converted to electricity for transmission. The economics of such arrangements would appear to be so unfavourable that they could succeed only where pipeline transportation to an adjacent market is not practicable.

The costs of producing natural gas from deep water will be high but not impossibly so. Neglecting the influence of inflation, which can be assumed to affect all systems equally, it might be hazarded that improved technology will enable the deep gas to be produced at, say, three-quarters the cost of gas developed by platform drilling in 150 m of water.

(*b*) *Load factor correction*

Notwithstanding that the discoveries of natural gas over the next few years are sufficient to meet the demand for premium uses, there will be problems in matching conditions of supply to the needs of the customer. As production sources become located in deeper water and increasingly far from shore, the penalty for operating on other than base load will become increasingly heavy. On the other hand as the load becomes increasingly of the premium variety the load factor of use will drop. This is a recognizable feature of gas industry planning today, but the problem is expected to grow more acute into the 1980s and some current measures of alleviation may no longer be practicable. Official policy for energy conservation may prevent the deliberate marketing of a proportion of the gas into bulk heat markets on long interruptible type contracts as a method of load factor correction.

(*c*) *Liquefaction for storage*

A method of peak shaving which has a particular additional value in improving system security is that of the l.n.g. plant. Natural gas from the pipeline is drawn off at a low rate throughout the year, liquefied and stored at its atmospheric boiling point of -160 °C in large heavily insulated tanks, probably of stainless steel, 9 % Ni steel or aluminium, but sometimes in other countries of concrete. At times of peak demand the liquid is regasified, and since a volumetric change of approximately 600 accompanies the change of phase, a moderately sized tank can accommodate a large amount of gas. Thus, a single cylindrical storage tank approximately 42 m diameter and 38 m high would hold 21000 tonnes of l.n.g., which, on evaporation, would provide 30×10^6 m^3 of natural gas. The whole of this volume can be released in a matter of 4–5 days if required. By siting the installation near the end of a spur main, in addition to providing peak load supplies it can also be used in the event of a transmission system failure to maintain supplies up to the point of failure. The maximum advantage can only be derived from such installations with freedom to site them in close proximity to particular points on the transmission system and if this is frustrated by purely local objections, notwithstanding the agreement of the competent planning authorities, much of the utility of the method will be lost. There is a growing tendency towards objecting to every incursion into the existing environment, however negligible the damage or worthless the *status quo*. If this tendency is not rationalized the 1980s may be a less comfortable era than the promise of the 1970s would indicate.

(*d*) *Storage of gas under pressure*

The storage of gas under pressure in vessels, whether above or below ground, can be of significance only in a system of local distribution and even 'linepack' – the volume of gas that can be liberated from a high-pressure pipeline when the pressure is dropped – is of little national significance. This is not often appreciated but derives from the fact that, in general, the extra gas is required generally just when the demand is highest and the flow of gas in the transmission line is causing the greatest pressure drop, thus minimizing the further pressure drop available to liberate 'linepack'. It does of course help to cushion the effects of sudden demand changes and may have particular utility in the period immediately after commissioning a new pipeline when the designed load has not fully developed.

In the volumes required to be meaningful to the transmission engineer, the storage of gas under pressure is limited to storage in geological formations, either man-made or naturally occurring. Such storages are likely to play a significant role during the 1980s. One possibility is the storage of gas in caverns leached in deep salt measures, and construction of one such facility by British Gas, near to the coast in the East Riding of Yorkshire, is already under way. In the chosen locality a bed of continuous salt some 150 m thick lies at an average depth of 1800 m, and in this bed storage 'bottles', each of approximately 220000 m^3 capacity, are to be leached. At this early stage of development it is not possible to define precisely the pressure range over which the storage will operate, that will depend upon the 'creep properties' of the *in situ* salt, but it is expected that about 30×10^6 m^3 of gas will be recoverable over, say, 50 days, at such a pressure that it will pass straight into the adjacent main transmission line. We envisage being able to construct two cavities at one time, taking water from the sea and returning the strong brine; the construction time is necessarily long and a pair of cavities is likely to take about $2\frac{1}{2}$ years to complete. By the early 1980s we would expect to have some 120×10^6 m^3 of seasonal load gas available from this source, and if the development meets with early success other sites will be sought for parallel developments. A small storage with a releasable capacity of only 3×10^5 m^3 and in a shallow salt bed has been operational as a town gas store for more than ten years, demonstrating that the method is sound in principle, but British Gas is now seeking to operate salt cavity storages at greater depth than has been experienced anywhere else in the world and there are some rheological problems.

Investigation has been made of the possibility of storing gas in disused collieries or other mines, but the problems of achieving secure leak-free storage in hard rock which has been subjected to mechanical mining methods are many and this method does not look promising in the U.K. at least. Equally, it has proved difficult to locate aquifers, having all of the required geometric and geologic properties necessary for secure gas storage, of sufficient size to be economically significant and sufficiently remote from potable water sources to be practical. Many potentially interesting prospects in the U.K. have had to be abandoned after intensive study and even the famous Chilcomb Anticline, near Winchester, the cause of so much Parliamentary Debate at one time, would be only marginally attractive in the economic scenario of natural gas. It is more probable that as fields in the southern North Sea begin to deplete, and the costs of recovering natural gas from farther afield and deeper water begin to have a significant impact, that some recharging of depleted offshore fields will be undertaken. Throughout the land mass of Western Europe, however, a number of onshore aquifer storages are in operation already and the number can be expected to grow steadily as suitable sites are discovered.

(*e*) *Manufacture of natural gas substitutes*

As a means of providing peak supplies of gas, British Gas will increasingly make use of its range of unique processes for the manufacture of a natural gas substitute. These processes, based upon the pioneering researches of Dr F. J. Dent, F.R.S., in the field of pressure gasification, have already played an important part in the resurgence of the manufactured gas industry in the 1960s, but are likely to reach their full development in a natural gas environment. The novelty of Dent's work lay in his concept of the direct conversion of carbonaceous raw materials to methane, rather than by the classical route of gasification to form synthesis gas followed by methanation, a highly endothermic process followed by a strongly exothermic one, with all the losses inherent in the large-scale heat recovery which becomes inevitable.

The preferred route for s.n.g. production, particularly for peak-load purposes where low load factors of operation and swift changes in load dictate relatively simple plants capable of semi-automatic operation and of low specific capital cost, is by the catalytic rich gas (c.r.g.) process. Lighter petroleum fractions which are capable of being vapourised and purified so as to contain not more than 0.2 parts/10^6 of sulphur can be reacted with steam at about 450 °C over a highly active catalyst to form a mixture consisting essentially of carbon dioxide and methane and requiring only simple removal of carbon dioxide to provide a satisfactory natural gas substitute. Three former town gas manufacturing plants have been converted to s.n.g. manufacture to provide a full-scale demonstration of different variants of the c.r.g. process which is the basis of the majority of s.n.g. plants now being constructed in the United States in the face of the rapidly developing natural gas shortage. Eighteen streams of plant with a total capacity of a little over 2×10^6 m^3/h have been ordered; of these, two are already in full operation and seven others are nearing completion.

British Gas is now proposing to convert a few more plants to provide additional peak-load substitute natural gas until the new supplies of natural gas from the Frigg and Brent Fields become available. However, in the 1980s it is unlikely that these converted plants will play a major role and plants specially designed and located to meet the specific load conditions at that time would be constructed.

Catalytic gasification cannot be applied directly to the heavier non-vapourizable oils or to crude oil, but in these cases it is possible to hydrogenate the whole feedstock to gaseous hydrocarbons, principally methane but containing some ethane and possibly some higher hydrocarbons as well. The hydrogenation reactions are strongly exothermic and, if secondary cracking is not to occur, careful temperature control is required. With the lighter oils this can be achieved in a simple cylindrical reactor containing a concentric tube into which the main reactants are injected in such a manner as to cause a rapid recycling of product gas. This is the so-called gas recycle hydrogenator (g.r.h.), a brilliant product of Dent's fertile imagination. With heavy and crude oils, although the main mechanism of hydrogenation is similar, the breakdown of the molecules is accompanied by the production of some particulate carbon. Accordingly, the reaction is conducted in a bed of coke particles fluidized with the hydrogenating gas, thus providing nuclei for the agglomeration of the particulate carbon as well as establishing a close degree of temperature control. This fluid bed hydrogenator (f.b.h.) process is currently being operated on the semi-commercial scale in Japan and will most certainly be available for fully commercial use in the 1980s. It is, of course, an inherently more complicated gasification route than c.r.g. Part of the rich gas product from the hydrogenator must be recycled through a steam reformer to provide the hydrogenating gas or alternatively part of the heavy feedstock must itself be gasified at pressure to produce hydrogen, for example, by a partial oxidation process. Not unexpectedly the specific capital cost of the hydrogenator process is higher than that of c.r.g. and the minimum economic scale is also greater, but a wide range of feedstocks right down to at least light crudes can be accepted.

It is impossible at this stage to predict with any accuracy the part which each of these processes will play in the 1980s. If naphtha were to be available at prices reasonably closely related to the cost of crude, then the c.r.g. process alone would be utilized. However, it seems more likely that British Gas might have to contemplate utilizing some of the whole crude that by 1980 will be flowing from oilfields in which it has an equity stake. In these circumstances the choice will lie between using the fluid bed hydrogenator to gasify the whole crude or carrying out a simple distillation to give a fraction suitable for catalytic gasification, a second as feed for a hydrogenator with the residue being used as a source of hydrogen. While the need is principally for peak-load gas it is probable that a solution based upon running a small base-load crude distillation unit and storing the catalytic process feedstock against the time of extreme demand will turn out to be the more viable but all of the detailed technical and economic studies required to elucidate this choice have not yet been conducted.

British Gas also has in principle the capability to make s.n.g. from coal by methanation of carefully purified lean gas derived from, say, a Lurgi gasification plant. Trials of such a process combination are currently being conducted at the Westfield Plant of the Scottish Region of British Gas on behalf of a consortium of U.S. companies led by the Continental Oil Company. While this remains a technical possibility, however, it seems unlikely that a coal based process would be economically viable in U.K. in the 1980s for base-load production of s.n.g., let alone for peak-load purposes. But British Gas intends to keep in close touch with coal gasification technology and hopes to be able to contribute its fund of know-how in this area to cooperative development schemes in exchange for access to the data obtained. By this means a move back into coal gasification could be made at short notice if it became necessary.

3. GAS PIPELINES

(*a*) *Design parameters*

In a highly developed countryside like the U.K. the typical pipeline is 750–900 mm in diameter; it operates at a maximum pressure of 6.9 MPa; it is made from a ferritic steel with a very low alloy content, a yield strength of about 460 N/mm^2 (30 tonf/in^2) and a high resistance to both brittle and ductile rip; it is designed to have a hoop stress of not more than 72% of the minimum specified yield, giving a wall thickness in the region 7.5–12.5 mm.

Throughout the 1980s there does not seem much likelihood of a major stretching of these parameters. While there is an economic incentive to go for higher pressures and larger diameters this is offset by worries about security of supply in the event of a failure and resistance from authorities concerned with safety regulations. The use of a higher strength steel is not justified unless it can lead to a pipeline at a lower cost but such estimates as British Gas has made provide, at best, a marginal case. In any case, wall thicknesses ought not to go below about 9 mm in developed countries; this thickness of steel will resist blows from quite a wide variety of digging implements while lesser thicknesses are easily penetrated by quite common tools such as picks.

(It is frequently not appreciated that by far the most common cause of failure on a major pipeline comes from external interference.)

In remote areas, in stable ground, where there is little chance of pipelines being damaged and where there is a low risk of hazard if there should be a failure, designers will attempt to reap the economic advantages. Pipelines working at pressures up to 10 MPa and even higher in special circumstances will be met. In such remote areas where there is no need for frequent offtakes and interconnexions, the pipeline is subject to only very simple stressing conditions and the design stress will probably be raised to about 80% of the yield.

A diameter of 1200 mm is probably the largest pipe size yet laid in the West, but with the expected growth in gas supply we might expect to see up to about 1500 mm diameter in the 1980s for the transmission of gas in very large bulk from some remote area. Under these conditions there could be an incentive to use higher-strength materials, but this should present no difficulty as weldable steels of much higher strength and toughness than currently in use for line pipe have long been in use in other engineering fields.

The diameter and wall thickness of pipes are somewhat limited by problems of avoiding distortion during handling and by earth loading. The maximum diameter/thickness (D/t) ratio in current use today is about 75 and it has been estimated that a ratio of 120 probably represents an absolute limit even with the development of new machinery – for example, for making field bends. There is already a tendency to buckling in this process and at higher D/t ratios this would become intolerable.

Undersea pipelines are subjected to different conditions and a number of problems are met during laying, particularly when the water depths exceed about 50 m. The pipeline curvature onto the sea-bed has to be controlled in order to prevent a running buckle along the pipe length: this places a major limitation on the D/t ratio. At sea depths of 600–1000 m the water head would collapse most pipes at present in use and for the future even heavier weight pipe, possibly with stiffeners, will be necessary. As wall thickness increases so we can expect pressures to rise to take advantage of the inherent strength of the pipe wall. Pressures up to 20 MPa or more may be used and pipe wall thicknesses will be approaching 40–50 mm but there does not appear to be any requirement for the use of materials of very high strength.

(*b*) *Welding*

In all pipelining work increasing use will be made of automatic welding processes. No major problems with weldability of the steel should be encountered, since all of the high-strength, high-toughness steels mentioned have low carbon contents (0.15% maximum but usually below 0.1%), and this is a major determinant of good weldability. One can foresee, therefore, the principal problems being the application to field construction conditions of automatic processes of the metal-arc inert-gas shielded or self-shielding electrode types originally developed for use in other applications. Particularly where heavy wall sections are employed, the emphasis will be on high metal deposition per run to achieve maximum economy. British Gas already has experience of the use of fully automatic welding equipment in the construction of a major pipeline and it can be confirmed that the quality of welding was excellent. A high rate of production was achieved only after a very considerable technical effort in the early stages of the job; there is no intractable scientific problem to be overcome, but further engineering development is necessary.

Particularly for submarine pipelines, use may well be made of the technique of explosives welding which by 1980 should have developed to the stage at which it is only limited by environmental noise considerations. Explosive techniques will employ a sleeve which is welded either to the inside or outside of the carrier pipe. In either case the explosive force will have to be contained by a mandrel which when used on the inside of the pipe could serve as a line-up clamp. A related technique of explosive crimping might also be used under water to quickly shut off leaking oil or gas lines.

(*c*) *Special materials for pipelines*

Pipelines have been built in aluminium, stainless steel, reinforced plastics and so on, but all for special purposes, and it does not seem likely that such material will find widespread use for simple gas lines. However, the need for larger-diameter pipes may favour the use of spirally welded pipe, since the ingot size and hence plate width that can be handled in any particular pipe mill places an upper limit on the diameter of longitudinally welded pipe that can be produced. By 1980 systems of producing spiral-weld pipe on site may have been developed to a stage of real practicability and this would then open the way to consideration of the composite spiral pipe. Improved properties could be obtained in large diameter, thin-wall pipes, if they were to be built up from several layers of thin sheet, just as plywood has certain structural benefits over single sheets of wood. Given adequate spiral-pipe technology one could imagine the continuous production of composite pipe by the use of thermosetting resin adhesives between layers of steel strip. Such pipe should be inherently tough and very flexible and, if the process could be adapted to manufacture on a barge offshore, it might be a major factor in overcoming the problems of deep-sea pipelines.

(*d*) *On-line inspection*

It is standard practice for British Gas and some of the other leading gas transmission authorities to subject a new high-pressure pipeline to an initial hydraulic test at pressures maintained for 24 h which result in stresses up to and beyond 100% of the minimum specified yield for the pipe in question. Such testing is usually called 'high level' or 'yield' testing. The philosophy is straightforward. All defects grow at a rate dependent, *inter alia*, upon the level of applied stress and the higher the pressure to which the pipe is subjected, the more likely it is that any defects left in the line after construction will grow to significant proportions, open up, and leak even if they do not cause a major failure. Defects left after high-level testing will be very small, often so small as to be insignificant, but certainly giving a good margin for subsequent growth with time under the much lower working stress. It is worth noting that in over 16000 km of pipeline tested in this fashion experience has indicated that 72% of the defects detected were found at stress levels above 80% of the specified minimum yield, with 47% occurring above 100%.

Having gone to so much trouble to ensure the quality of the pipeline as constructed, it would be illogical not to attempt to measure changes in service, and this is now receiving increasing attention. For example, the I.G.E. Code of Practice TD/1 'Steel pipelines for high-pressure gas transmission' dated 1970 seeks to establish requalification of a major high-pressure pipeline every seven years. To do so by repeating a high-level hydraulic test will be time-consuming and expensive. In most circumstances it will be impracticable also since there is rarely sufficient transmission capacity on alternate routes to permit a pipeline to be out of service for several months even at times of low load. There is thus a considerable interest in techniques for inspecting the condition of pipelines remotely and without taking them out of service.

By the 1980s the use of on-line inspection techniques via remote-reading apparatus will have become widely accepted by pipe-line owners. The current simple expedients of checking cathodic protection, line-walking and helicopter surveillance will be backed up by complex internal devices or 'pigs' which will scan the inside of a pipe while the gas is flowing, to locate, interrogate and record defects. The data collected will then be used for quantifying and testing the defects for significance by computer-based machines.

Magnetic devices already exist which have some measure of ability in this direction, but they are in their infancy and require considerable further development. As yet they cannot differentiate between a large defect on the outside surface of the pipeline and a small and insignificant defect on the inside surface, and discrimination is the biggest problem of all. Eddy-current devices are also available and these will be adapted and developed to operate alongside the magnetic devices to ease the problem of discrimination, but more sophisticated techniques are required to inspect the zones around the welds which are more likely to contain important defects than the more easily inspected parts of the pipe wall. Techniques, such as elastic wave propagation (ultrasonics) may be suited to this difficult inspection role and such devices are being actively studied.

On-line inspection has an obvious application in high-density population areas where maximum safety is of paramount importance. Equally, it could be of considerable benefit as a monitor on remote pipelines and undersea lines where repair equipment can often only be deployed at a particular season. Thus, a forewarning of the state of deterioration of a line could enable preventative maintenance to be carried out at the most convenient time.

Much of the basic data about how magnetic fields are changed, and how ultrasonic waves are reflected, by different geometries, does not exist; a programme of physical measurement and developments of theories are needed to support progress. The growing science of fracture mechanics will also provide much data about the significance of the defects once they have been quantified. This is one of the most exciting developments which can be foreseen, but it is also one of the most difficult. However, compared with the task of repairing a pipeline, to eliminate the defective section, the cost of the detection system will be small and there is every economic incentive to progress this matter.

(*e*) *Gas compression*

In many existing transmission areas the already large capital investment in gas compression facilities will preclude any major changes in philosophy, and additions to the system are likely to conform largely to present practice. However, the increasing cost and demand for natural gas will put emphasis on the conservation of compressor fuel gas and give incentive to install or modify existing units to give higher overall efficiency.

For ease of maintenance and replacement and to accommodate to rapid load changes and quick starts, British Gas normally uses modified aircraft-type gas-turbine units as prime movers in its gas-compression stations and this trend is likely to continue. Current engines, both the Avon and the Orenda, have overall thermal efficiencies of about 25%. Second generation aircraft turbines such as the Spey and RB 211 have thermal efficiencies of up to 35% and will clearly come into service whenever the larger power of these units can be utilized economically.

A typical single-stage centrifugal compressor has an efficiency of approximately 80% for low compression ratios and this is difficult to improve upon. Axial flow compressors with perhaps variable-geometry blading show promise of efficiencies of the order of 90%. If such compressors can be made robust and reliable, large savings can be made for large volume flows. The problem will again be one of how best to incorporate these large machines into the network without losing flexibility or reducing system security in the event of mechanical breakdown.

The trend to remotely operated unmanned compressor stations will continue and into the 1980s there will be an increasing tendency to make compressor stations fully automatic.

(*f*) *L.n.g. pipelines*

The technical feasibility of l.n.g. pipelines has been established but current information suggests that the cost of transmission can only be competitive with a gas line for a transport distance of over 2000 km. The number of routes of this length without a major offtake are not likely to be great and no more than very limited use of this technique can be foreseen for the 1980s. Specific engineering problems remaining to be solved include the design and construction of the insulation casing, dealing with the effects of any flow stoppage, the causes and consequences of line fracture, line vent design, and the problems of filling the line and of starting up. In one case-study it took three years to fill the line initially with liquid; the operational methods put forward in another outline proposal would have resulted in all the liquid evaporating before it reached the end of the pipeline.

4. Some practical problems of transmission networks

(*a*) *Design*

Until quite recently the techniques for the design of gas transmission systems have been relatively crude. Only in the mid 1960s did computer techniques for calculating flows in branched networks come into general use and they were limited to non-compressible flows and steady-state conditions and hence were mainly of use for the low-pressure distribution system. At the end of the 1960s computer programs which could calculate transient effects in a network under compressible conditions became available; such calculations now form the basis of operations in the U.K. One of the major problems in design of a complex network becomes the identification of the 'crucial case' among the whole array of possible unsteady-state conditions and further developments in computer technique will be necessary to keep the number of design calculations within reasonable limits as transient analysis becomes the routine design method.

(*b*) *Flow measurement*

The basic measurements of gas entering a transmission system are the flow and the energy value of the gas. Flow is measured by a pressure-difference device (usually an orifice) with a number of instruments making subsidiary measurements to permit correction for the effects of pressure, temperature, etc. The accuracy achieved in good installations is about ± 2% on flow and ± 0.5% on pressure, and this level of accuracy is sufficient for day-to-day control purposes. But unless considerable care is taken, accuracies very much worse than this will be met in practice and single effects producing errors of up to 17% have been found in some places.

No national or international standard flowmeter prover exists, nor is one likely to for several years on the scale required by British Gas. The annual turnover of the industry which makes flowmeters is only a small fraction of the cash flow which for British Gas is determined by less than 20 main orifice meters and it seems likely that further advances will depend on the initiative of gas industry itself. The possibility of using techniques such as radioactive tracers, laser/Doppler scanners or critical pressure nozzles as provers is clearly present; at the very least they would ensure consistency but can probably offer a considerable improvement in accuracy as well.

The application of modern design methods to subsidiary instruments such as calorimeters and specific gravity meters will also improve the overall accuracy considerably; these instruments have had no real design attention for several decades, until quite recently.

(*c*) *Flow control*

Flow control is increasingly being carried out remotely and small blocks of digital computers can be used for this purpose. For the operation of instrument signalling systems and for the control of smaller items like valves and heaters at offtake points, there has been so far little automation and analogue devices have been used to combine signals from instruments, the final result being entered into the telemetry system via an analogue/digital converter. Increasingly, small digital units will take over these functions and, in addition to arranging telemetry data, they can be expected to carry out simple control functions such as turning heaters on and off, and adjusting valves. Although some manning will still be required for maintenance purposes, the small satellite computer will become an integral part of operations in the 1980s either to give cheaper systems or more often for greater security.

5. Postscript

The trends in future gas production and transmission have been examined with specific reference to the United Kingdom, but in a technical sense they are equally valid for the whole of Western Europe. However, the extent to which certain lines will be followed will depend critically upon the pattern of energy development in the country concerned and this will frequently be determined, or at least influenced to a major extent, by political factors. While Britain can look forward to a plentiful supply of natural gas during the 1980s from her own indigenous resources, if these are utilized to meet part of the larger market in Western Europe a decline in availability would soon set in, without in the meantime doing a great deal to ease the problems of the region as a whole. It seems likely therefore that there will not be a common pattern of natural-gas development thoughout Europe, and countries lacking indigenous sources will largely have to depend upon imports from outside Western Europe by gas pipeline or by l.n.g. tanker, supported by manufactured substitutes for peak shaving and to give a measure of security against loss of supply. Such major imports will often pose difficult matters of politics, and in such circumstances a lower rate of growth of gas load should be expected.

Discussion

Mr A. B. Lovins (c/o *Friends of the Earth Ltd*, 9 *Poland St*, *London W*1*V* 3*DG*)

Do modern gas pipelines have joints and metallurgy appropriate for the transmission of hydrogen instead of methane, or would the design have to be altered to make the pipelines suitable for this purpose?

D. E. Rooke

Yes the materials are satisfactory, but with hydrogen the pipes would have less thermal carrying capacity and more power would be needed to compress the hydrogen.