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CRES General Paper
EC/GP6 (1979)

ISSN 0314-738X ISBN 0-86740-232-6

The Australian National University
Centre for Resource and
mental Studies

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Production Technology

The technology of oil well drilling and oil production has progressed a long way since the use of cable tool rigs in the early 1920s. In those days drilling was carried out by a method whereby steel bits were fastened to a heavy metal rod which was raised and dropped by means of a steel cable. The rock at the bottom of the hole was chipped by impact of the weighted bit. Accumulated chips, mud and water were removed from the bottom of the hole by means of a bailer, a cylindrical device having a valve at the lower end, which could be lowered down the hole. Flow of formation water into the hole, and caving sidewalls were controlled by setting steel casing which was lowered down the hole and cemented into place. As the hole was drilled deeper the diameter of the casing decreased and the bits used were smaller. Depending on the depth to which the hole was to be drilled, the diameter of the surface casing ranged up to 75 cm, and that of the bottom casing ranged down to 10 cm. Drilling was slow, depth was limited, and control was uncertain at best. Many a well was ruined because of unforeseen caving or water flooding before casing could be set, and many others blew out and caught fire on striking accumulations of oil and gas under high pressure. Where the oil was not under sufficient pressure to rise to the surface, its presence was detected in the bailer, and pumping equipment was installed to bring the well into production, the gas commonly being piped to nearby flares. This wasteful procedure of burning off the unwanted gas is no longer practised, with the exception of some very small flares, in most oil fields throughout the world.

The advent of rotary rigs placed the drilling of oil wells on a much more controlled basis. This method uses a cutting bit which is screwed into the bottom end of a string of drill pipe which is rotated by a turntable on the drilling-rig platform. Drilling mud, the density and chemical properties of which are controlled, is circulated down the drill pipe to the bit, and back up to the surface along the space between the drill pipe and the wall of the hole. Moving upward the mud carries cuttings from the rotating bit, and also sidewall cavings from the softer or more shaly rock layers. The weight of the column of mud, controlled by the addition of heavy substances such as the mineral barite (barium sulphate), prevents oil and gas under pressure from rising to the surface; although gas under exceptional high pressure, when encountered unexpectedly, may force the mud column to the surface and cause a blow-out. In areas where high pressure gas may be encountered, precautions are taken to prevent such accidents by installing a system of valves known as a blow-out preventer.

In the early days of rotary drilling there was no way of controlling the direction of the hole, particularly as there was no method of surveying the hole to plot its three dimensional shape and the position of its bottom. Most holes drilled departed from the vertical in a cork screw fashion, trending directionally in accordance with the type of rock and structure of the layers penetrated by the drilling bit. Such departures from the vertical could seriously affect the outcome of the well, causing the hole to completely miss an accumulation of oil. The invention of well survey instruments, and the development of directional drilling techniques, enabled wells to be drilled precisely to any depth within the

capability of the rig. It also enabled the drilling of up to 25 wells from one surface location, an important contribution to the technology and economics of offshore drilling where a number of wells can be brought into production from one platform.

Deep-water Drilling

As exploration for oil and gas proceeded farther from shore on continental shelves around the world, the technology of offshore drilling developed rapidly to meet the increasing demands for discovering and bringing into production the hydrocarbon resources underlying deeper water of the outer continental shelf. Various types of platforms were built, as mentioned in Chapter 4, including the Statfjord A production platform in the Norwegian sector of the North Sea. This giant platform sits on the seabed and rises 260 m. Such fixed gravity structures are best employed in water depths of about 150 m. They will probably be limited by cost (up to $(A) 500 million each in terms of 1979 dollars) and by their enormous size and weight (up to 300,000 tonnes), to depths of less than 300 m. Because of the severity and unpredictability of weather conditions in many of the offshore regions of Australia, and also because of costs, it is unlikely that very large fixed structures will be designed for offshore drilling. Alternative types of structures, including guyed towers in depths greater than 200 m will probably be considered.

Exploration has now stepped beyond the continental shelf, on to the areas of the continental slopes. In these depths of up to 600 m flexible guyed structures or drillships must be used. Australian drill ships include the Southern Cross, Ocean Endeavour, and Regional Endeavour, the latter capable of drilling in depths of up to 460 m. In still deeper regions of the plateaus drilling must be done by

dynamically positioned drillships such as Sedco 472 which in 1979 drilled Esso-BHP Zeewulf 1 in some 1200 m of water on the Exmouth Plateau. Oilfields discovered in these great depths of water can only be brought into production if they are sufficiently large to warrant the costs involved, and then only by the development of an entirely new technology using submerged production systems operated and maintained by remote control. The technical problems to be solved are staggering, and although several possible designs are under consideration, to 1980 none of the proposed systems has been placed on a production basis anywhere in the world. Australia will, in this respect, be in the forefront of technological developments, provided an oilfield containing at least 300 million barrels of commercially producible oil is found on the Exmouth Plateau.

The Northwest Shelf gas project will bring into production the Rankin, Goodwyn, and Angel fields underlying a water depth of approximately 130 m. In deeper water of the continental slope it will not be possible to erect a fixed bottom platform, and other more flexible structures will have to be designed. The problems arising in placing a deep-water field on production are different to those involving production from the North West Shelf fields. Some future problems may currently be unknown. Others may have only recently been known. One such problem is the generation of internal waves beneath the ocean's surface. These have been photographed by earth satellites (McKinney, 1979) and apparently are generated along the boundary between layers of sea water having different densities, commonly where warm, less saline water overlies cold, more saline water. These waves range in amplitude to 180 m and can have a crest length of up to 200 km. Although generated at depth, they affect the surface water and consequently the movements of a drillship and

drilling riser. The latter, consisting of a pipe through which the drill stem extends from the ship to the wellhead on the seafloor, is supported by the drillship. The resulting tension is relieved to some extent by the addition of buoyancy materials to the riser. Bending stress, causing curvature, is another problem to which the riser has only a limited tolerance. For such reasons, unforeseen movements of the ocean, caused by internal waves, could cause serious problems.

On the Exmouth Plateau, drilling has been carried out in a water depth of 1200 m. Further modifications to the few existing drillships capable of operating at such a depth could enable them to drill in up to 1800 m of water. At this depth the drilling riser would, allowing for curvature, be more than 1800 m long and would be suspended from the drillship like a string, subject to the motion of the ship and to internal waves and currents. In the event that an oil field is brought into production on the Exmouth Gulf, similar problems may arise with the production riser through which oil flows to the surface of the ocean to submerged or floating storage facilities. The role of physical oceanography in assisting to predict the severity and possible seasonal variations of sea motions is obviously of great importance.

Planning Stage, North West Shelf Gas Project

The main project undertaken on the North West Shelf during the early years of the 1980s will be bringing the North Rankin, Goodwyn, and Angel gas fields into production. This is a mighty project involving the building of offshore production platforms and pipelines, a gas processing plant, liquefaction plant, and shipping facilities probably costing a total of $(A)3000 million in terms

of 1979 dollars. A great deal of technical and economic planning is required, based on government policies, market surveys, and on current and possible future developments in drilling and production technology, offshore construction, and knowledge of the physical effects of ocean and wind disturbances.

Preliminary surveys and investigations probably costing at least $(A) 50 million in terms of 1979 dollars, were planned in 1977. The object of these studies was to define the North West Shelf gas project in depth, and so minimize the possibility of unforeseen problems arising. Also, the cumulative information obtained from the several reports would assist in the formulation of final decisions on the economic feasibility of the project.

The studies proposed in the overall planning stage, to be undertaken within a two-year period, were outlined by McGrath (1978). These include a gas reservoir evaluation of the North Rankin, Goodwyn, and Angel fields; a drilling and production platform seabed foundation study; the selection of an onshore plant site; harbour facilities investigations; a submarine pipeline survey; environmental studies; design studies; market surveys for petroleum products; investigations of shipping requirements; and last but by no means least, inquiries into the avenues available to finance such a huge project.

Evaluation of the gas reservoirs entails detailed seismic surveys and possible drilling to further delineate the geological structure of the gas-bearing rock strata in order to up-date prelimiary estimates of proven and probable gas reserves, and to assist in the placing of production platform sites. It is planned to build two platforms, and seabed surveys have been undertaken to determine the nature of the seabed sediments on which the platforms will rest. These surveys have found that in the area of the North

Rankin field, where the water depths are approximately 130 m, the seabed consists of unconsolidated calcareous sediments having a low bearing and shear strength. Such information greatly assists in designing a suitable structure for the platforms. Plans for North West Shelf gas production envisage two steel structures, each having an overall height of about 200 m, built to withstand the maximum possible buffeting from cyclones. The drilling and production platforms supported by these structures will include plants to process the gas.

Hydrocarbons from the production platforms will be carried by a pipeline to the onshore treatment plant near Dampier. The pipeline will probably have a diameter of about 90 cm (36 inches) and a length of approximately 140 km. The route of this pipeline, and possible problems related to stabilization in the seabed and underwater connections, will be determined by preliminary studies of the seabed and other aspects of physical oceanography. A further pipeline, to run from the treatment plant south to connect with the existing gas pipeline between the Dongara gas field and Perth, is also planned. The Dongara field will probably be depleted by the mid-1980s and may then be used as a storage reservoir for gas transmission to Perth. Other pipelines will probably be built, one to run from Perth as a spur line to the industrial centre of Pinjarra, and another from Dampier to the iron ore processing plants in the Pilbara region. The selection of a site for the onshore gas treatment plant and other processing facilities depends on investigations of a number of physical, biological, environmental and socio-economic factors.

Further seabed and land topography studies are required as a basis for the selection of suitable harbour sites and docking facilities for shipping. Investigations are also needed with reference to

the types and number of vessels required to ship LNG (liquid natural gas) and condensate, and the ownership and conditions under which such ships might operate. Other studies entail the viability of different designs for onshore construction and all the associated infrastructure. Estimates must be made of the probable costs. International market surveys must also be carried out, in a changing climate of uncertain prices and unstable markets, on the long term economic viability of the project. These entail negotiations, influenced by a background of largely unpredictable political and economic events, which conclude with the signing, by parties offering to sell and buy the petroleum products, of letters of intent. Concomitant with such negotiations are inquiries into the avenues of international banking by which the project could be financed. And finally, the results of independent studies must be incorporated in an environmental impact statement which will be judged on the basis of objectivity, and weighed with reference to the socio-economic advantages of development on the one hand, and the socio-environmental disadvantages on the other.

LNG and Condensate Production, North West Shelf Gas Project

Liquefied natural gas (LNG) is distinct from liquefied petroleum gas (LPG). Both are distinct from condensate. Condensate is a light petroleum liquid obtained from the cooling and expanding natural gas that arrives at the surface from producing wells. It is used as a refinery feedstock, and in the 1920s was also sold as a motor spirit. Condensate includes a mixture of lighter liquids in the paraffin series, such as pentane, hexane, heptane, and octane. Higher in the paraffin series, the hydrocarbon propane is a gas at normal pressures and can be readily liquefied to LPG by compression at normal temperatures. The basic member of

the paraffin series is the gas methane, the main constituent of natural gas, which can also be liquefied as LNG under pressure and considerably reduced temperature. Shipment of LNG requires cryogenic conditions in specially refrigerated ships.

Some of the gas produced from the North Rankin, Goodwyn, and Angel fields will be pumped through pipelines to Perth and other centres in Western Australia, for industrial and domestic uses. Eventually, gas may also be moved to Sydney by a transcontinental pipeline connecting with the gas fields of South Australia. But the bulk of the production will be shipped overseas, and beginning in 1984 it is planned to export about 6.5 million tonnes of LNG each year. Condensate will also be produced at the rate of about 8 million barrels a year. Much of the gas would go to Japan, and some may go to the United States, being transported in six or more large cryogenic tankers. By comparison, the export of LPG during 1979 was somewhat less than 1.5 million tonnes.

The production, liquefaction, transportation, and storage of gas requires an integrated and syncronized system, planned to operate for a period of at least 20 years, as outlined by McGrath (1978). Plans envisage that initially two drilling platforms will be towed upright on their supporting structures to sites where the structures will be lowered and secured to the seafloor. From each platform 20 or more wells will be directionally drilled into the North Rankin gas field. Processing plants on the platforms will remove water, sand, and some condensate from the gas before it is pumped through a pipeline to the treatment plant on shore.

The treatment plant will extract the remaining condensate before the gas passes to a liquefaction plant. LNG is produced by cooling the gas to minus 160° Celsius (-261°F), at which temperature the liquefied natural gas can be stored at atmospheric pressures.

LNG may be stored in double-wall steel tanks, each holding up to 100,000 m^3, or pumped through pipelines to cryogenic tankers. The constructions of facilities to berth these tankers, which draw up to 12 m of water, may require substantial dredging operations in the harbour. Each tanker will have a capacity of about 125,000 m^3 and a length of nearly 300 m. At its destination in Japan or elsewhere the LNG will be discharged from the tankers into insulated tanks from which it can be regasified and transported by pipelines as required.

Economic Considerations

Government Policies

The production and marketting of LNG requires not only the integration and synchronization of a technically complex system, but also the sanctions of governments in both producing and importing countries that will allow the system to operate efficiently over a period of years. On the part of governments in the producing country, this means that approval must be given to the producing and marketting interests to determine a certain level of profitability. Such approval may involve permission to export a maximum volume of LNG over a stated period, concessions with respect to taxation, and agreements on investment allowance deductions and the definition of allowable capital expenditures, as mentioned by Charlton (1978). On the part of governments in the importing country, assurances must be given that the necessary LNG terminal may be constructed at a suitable site, and that imports will be maintained at certain levels for stated periods of time. The high costs of establishing the system

require long term commitments to production and sales. The above comments apply particularly to a system in which industry is the principal operating agent. Alternatively, governments may be directly involved in the ownership or operation of such enterprises through Crown companies or authorities whose responsibilities may be to participate in, regulate, or monitor the operations of industry. These matters are subject to negotiations and government policies, but are best resolved in a climate of political stability in which long-range plans can be made with reasonable assurance that they will not be upset by later government intervention. At all levels of government and bureaucratic decisions, integration and implementation of planning should be accomplished with the least possible friction and delay.

There are many considerations involved in the policies of the governments of both exporting and importing countries with reference to the production and marketting of natural gas. Policies may, in varying degrees, reflect political philosophy or expediency. Exporting countries are, on the one hand, concerned with the development of their economies and an equitable distribution of revenue between the oil industry and the government; and on the other hand, they are concerned with the conservation of a valuable source of energy. Importing countries are concerned with effects on their economies of the prices they will have to pay for LNG and other energy sources, and also on their dependence on other countries for fuel sources to which they have committed vast capital expenditures and industrial infrastructure. Diversification of energy supplies has become a key issue in the formulation of a rational political economy. Unforeseen contingencies will always arise, and Charlton

(1978, p.12) has pointed out, with reference to the overseas sales of LNG, that,

> "Because the contract is a long-term one, there will also be provisions aimed at maintaining such a reasonable market value in the future under changing conditions. However, it will be clear to both sides that no contract can be devised which will, with certainty, take into account all the changes and vicissitudes of a twenty years period. Accordingly an essential feature must be the creation of a sound relationship between buyer and seller, so that when problems arise in the future in intrepreting the contract, there will be the necessary measure of trust and mutual understanding."

Concomitant with such relationships between industries in each country, the governments concerned must also encourage the enterprise by assuring a measure of stability with regard to export and import controls, fiscal policies, and foreign exchange regulations.

Pricing and Export of LNG

Export of Australian LNG will be to any or all of three highly industrialized world trading zones, Japan, United States, and Europe. As with sales of coal, in which transactions the prices determined for shipments to these regions from other parts of the world are very much a matter of negotiation, there is no simple or arbitrary solution to the problems of pricing LNG. Inevitably, the prices must be related to costs of production and marketting, and to the prices obtained for alternative fuels. Government policies exert a significant influence in this area of trade negotiations, as do the well known laws of supply and demand. Cheap gas tends to encourage greater use, possibly at the expense of alternative fuels, and consequently leads to greater dependence on a less diversified system of supply. On the other hand, expensive gas may lead to

restriction of its use and constraints on the development of the economy. During the past decade the prices for natural gas at the well head and city gate have increased very considerably, and long term contracts for sales include escalation clauses that hopefully will allow for periodic adjustment of prices in terms of real dollars. The difficulties involved in such negotiations can be readily seen, but not easily solved. As with the sale of coal, the present and probable future production costs of LNG, and terms of contract, are important factors in determining prices. World prices will probably vary in different countries at any point in time, and Australian prices will have to be competitive. The prices for North West Shelf gas will also be determined with reference to possible discounts on volumes consumed, and the costs of alternative fuels.

Costs of Producing and Marketting North West Shelf Gas

The initial costs of producing and marketting oil and gas are those of geological and geophysical surveys. These are comparatively minor with respect to the following costs of exploration and production drilling, laying pipelines, and construction of treatment plants and associated infrastructures. Prior to drilling, the initial phase of an exploration programme can cost from several hundred thousand to a few million dollars (in terms of 1979 dollars). Exploration drilling can range in cost from $30,000 a day on land, to $56,000 a day on the continental shelf, and $130,000 a day in the deep water of the continental slopes and plateaus. Depending on depth, nature of the strata penetrated, continuity of supply of material and personnel for the drilling rig, and the avoidance of accidental delays, drilling of a single well may take more than 60 days.

Once an offshore discovery has been made and determined to be of a size that would justify it being brought into production, the costs can run to hundreds of millions, or a few billion dollars. The deeper the water and greater the cost to bring a field into production, the larger that field must be. On the Exmouth Plateau an oil field would probably have to contain producible reserves of at least 300 million barrels to be economically viable. Currently, a gas field could not be brought into production at such depths, for economic and technical reasons. The development of offshore gas fields, for some years after 1980, will probably be confined to those of the continental shelf in water depths of less than 300 m.

Even so, the costs are enormous, and in the case of the North West Shelf gas project may exceed $3,000 million in terms of 1979 dollars. Some of the costs, for which allowance must be made, are peculiar to Australia. It is not yet possible to precisely predict the path of a cyclone striking the offshore region and coast of Western Australia, and allowances must be made for lost time during the various construction phases for periods of severe weather disturbances. In Bass Strait, which is not commonly subject to cyclones but which is an area of periodic heavy seas and high wind, it was found that up to 25% of construction periods could be lost as the result of bad weather. Another allowance that must be made is for industrial action that can tie up various sections of construction for considerable periods. Again, experience in offshore construction in Bass Strait indicates that up to 25% of the time initially allocated for construction can be lost by industrial action. A possible solution to the latter problem is the letting of contracts overseas for certain aspects of construction. This has already been

the practise for many years in the servicing of offshore drilling rigs, some of which are sent for maintenance and repairs to Singapore where facilities and skilled labour for such work are available.

In terms of 1977 Australian dollars the estimated costs for various phases of the North West Shelf gas project were stated by McGrath (1978) to be $900 million for two offshore drilling and production platforms with an associated pipeline to the gas processing plant on shore; $700 million for a gas liquefaction plant; $100 million for the gas processing plant; and up to $1,300 million for cryogenic tankers to transport the liquefied natural gas to overseas markets. Other costs of harbour facilities and pipelines to the Dongara field and industrial areas are additional. Also not included are the costs of constructing LNG receiving terminals and regasification plants in Japan and elsewhere, which costs are born by the countries to which the gas is shipped.

Financing the North West Shelf Gas Project

The magnitude of the problem of financing a giant operation such as the North West Shelf gas project has been succinctly stated by Charlton (1978, p.11) who says,

> "A project of this nature is characterised by an accelerating outflow of capital for a number of years before sales income is earned. The scale of the project in terms of capital requirements is so massive that, even with a broadly based partnership like the North-West Shelf Joint Venture, the need for finance from third parties is paramount. Even so, the partners themselves must find large sums, since outside finance will not be available to cover more than a proportion of cash needs."

Charlton points out that the first priority in securing acceptable finance is to establish a project that is technically and commercially sound. Long-term contracts for purchase of LNG must be arranged with financially secure customers. This point has also been made by Folie and McColl (1978, p.108) who say,

> "In order to develop a viable project, a market for LNG must be found where the purchasing parties are willing to enter into a 15 to 20 year contract."

A further consideration is that in order to secure an economic return on the massive capital outlay, exports totalling at least 6 million tonnes of LNG a year are required. In the case of the North Rankin trend, comprising the North Rankin, Angel, and Goodwyn gas fields, the Commonwealth government has approved the export of 6.5 million tonnes a year for a 20 year period. This amounts to about 52% of 1978 proven reserves in the North Rankin trend.

Apart from the technical and commercial soundness of the venture, lenders such as international banks are concerned about possible changes and constraints to foreign exchange regulations, inflation, and the introduction of new government policies during the term of the loan. Interest rates and other provisions are adjusted according to the estimates of risk involved. Financial arrangements of this magnitude are enormously difficult, being dependent on a number of inter-related factors. Money is not forthcoming until there is evidence of firm intent from potential customers to buy the required volumes of gas over an agreed long-term period. But customers may hesitate to commit themselves during times of changing economic and political situations, seeking to make more flexible or less costly arrangements. Potential customers may also encounter long delays in obtaining permission to import LNG. In

the case of the United States, agreement must be obtained from the Federal Power Commission, possibly on terms that are not satisfactory to the customer seeking to import the gas. Also, changing political relationships may be reflected in trading agreements and sales of gas from other countries. In this respect, the United States may elect to import more gas from Mexico at the expense of possible sales of LNG from Australia. Such matters are of prime importance to producers and buyers in the drafting of long-term agreements, and also to financial institutions in their deliberations on the terms of loans.

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