COMMENT ON OFF-SHORE MINING AND PETROLEUM – PRACTICAL PROBLEMS

By H. P. Williams*

In his excellent paper, David Maloney has mentioned the ancillary services necessary to support an offshore petroleum exploration project. This commentary will describe, in very general terms, what functions those services perform.

Relative to these services, this commentary could have taken another approach: to analyse the various contractual provisions and discuss the more important legal problems which arise such as indemnities, exclusion clauses and insurances. In most cases, however, such contracts do not involve peculiar legal concepts exotic to general contract law. Problems confronted by lawyers in drafting, and in assisting in negotiating these contracts, have more a commercial than a legal origin. Certainly there are statutory and other regulatory controls on these services which demand lawyers' attention and the more important of those measures will be mentioned orally in presenting this commentary.

However a broad understanding of the work to be performed under these ancillary contracts gives lawyers a useful perspective of the entire operation. For instance, some of the services necessitate the installation of "third-party" equipment on the drilling vessel. It is therefore essential for the drilling contract to allow for such installation. This in turn enables the lawyer to appreciate the extent of risks when questions arise as to indemnities against liability for loss of or damage to the rig, the hole and ancillary equipment and liability for injury to or death of employees of the various contractors. This perspective has other benefits: it enables the draftsman to appreciate the problems of synchronizing the duration of all contracts which assists in framing provisions as to the commencement and termination of each contract; and generally it gives the lawyer a better "feel" for the work which, if it does nothing else, assists him describe the work and the standard of performance required.

In the case of formation evaluation and testing an attempt has been made to describe not only what work is involved but also how it is carried out. The purpose of this is to give some indication of what those services will, and will not, accomplish. Public companies listed on Australian Stock Exchanges are required to furnish reports on developments in, and results of, exploration work. Clients seek advice on such matters as investment in, or financing of, exploration and development projects. These reports have their limitations, an understanding of which will help avoid reading too much into them.

A description of just the fundamentals of drilling operations would require more space than is available for this commentary. However to better appreciate the ancillary services and the part they play in the entire operation it is desirable to outline the basic elements of rotary drilling from an offshore rig.

The suite of services for which separate contracts are usually required are:

1. Drilling
2. Wellsite surveying
3. Work boats and transportation
4. Cementing
5. Formation evaluation and testing

6. Well Velocity Surveys
7. Miscellaneous Other Services

In discussing these services the explorer is described as the "Operator" in keeping with industry terminology.

DRILLING (see Diagram page 280)

Offshore drilling is, in most cases, accomplished pursuant to a contract between the Operator and the owner of the drilling vessel or "rig", the rig owner undertaking the work as an independent contractor and furnishing drilling and marine personnel to work the rig. The contract will specify, in a schedule, other necessary equipment, services and personnel to be provided by the Operator and rig owner respectively.

The types of offshore rig most commonly in use in Australia are the drill-ship (simply a ship-shape floating rig), semi-submersible (a floating structure with sub-surface pontoons and columns which are water-ballasted to provide stability) and the jack-up (a fixed drilling platform supported by columns or "legs" extending to the sea-bed).

Rotary drilling involves four main systems: power, hoisting, rotating and circulating.

Power is generated by internal combustion engines to drive the drawworks and turn the rotary table described below and to operate the other machinery and systems.

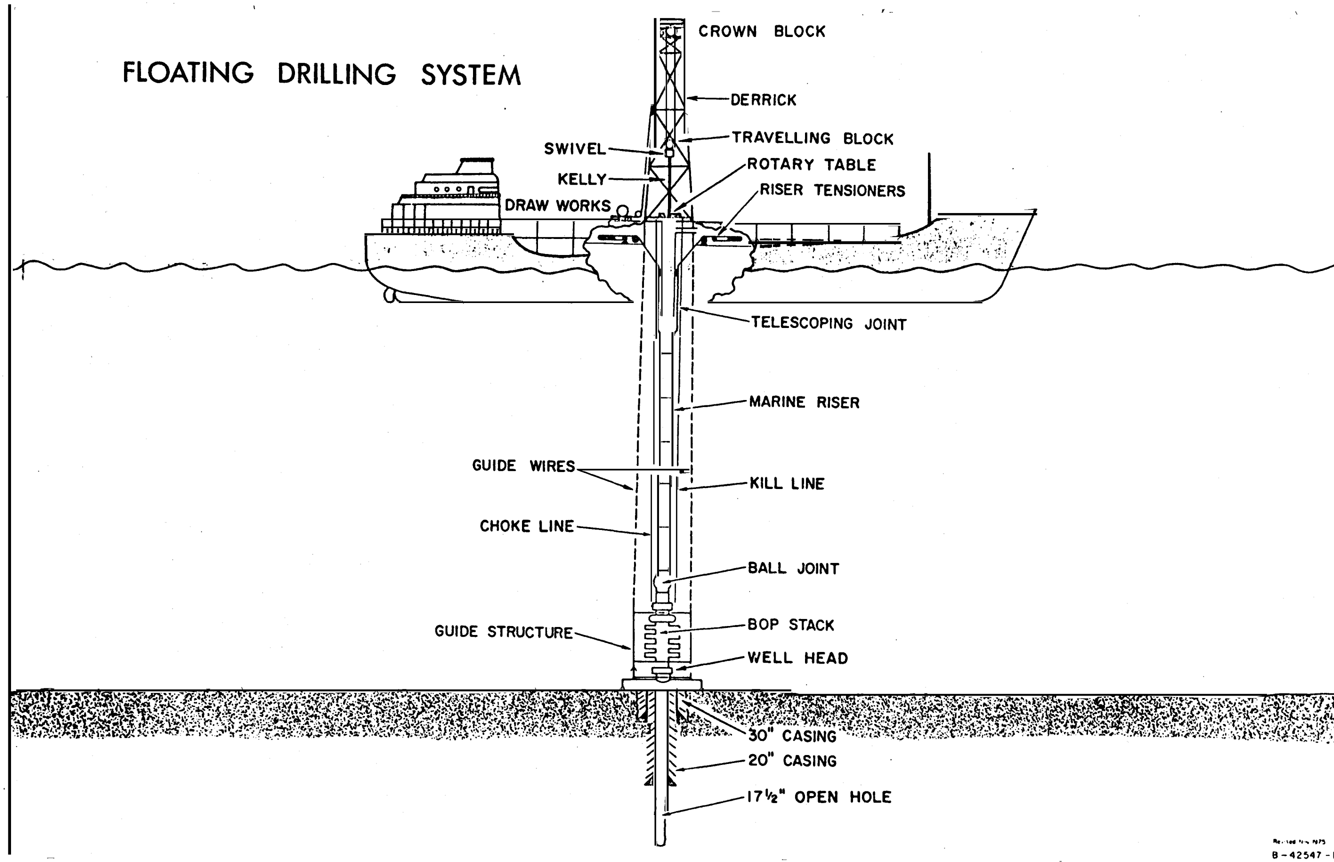
Hoisting is necessary to run drill-pipe and tools in and out of the hole and to lower casing. The system comprises the derrick; the drawworks (a revolving drum on the rig floor and around which wire cable is spooled); the crown-block (a block of multiple pulleys or sheaves at or near the top of the derrick through which cable from the drawworks is passed); thence to the travelling block below (a block of multiple pulleys moving up and down inside the derrick on the cable from the crown block).

Rotating equipment needed to turn the drill bit comprises a swivel hooked to the travelling block; a square or hexagonal length of pipe (the "Kelly") the upper end of which is connected to the swivel; and a rotary table set in the rig floor. The Kelly passes through the rotary table and transmits torque from the rotary table to the drill string (attached at the lower end of the Kelly) via a bushing which permits vertical movement of the Kelly as the drill string is lowered into the hole.

Circulating drilling fluid ("mud") from mud tanks into the swivel and down through the hollow Kelly and drill pipe, out through jets in the bit and back up the well annulus to the rig serves several important purposes. It cools and lubricates the bit and drill string; it carries cuttings back to the rig; it protects against caving in of the rock formation and against blowouts by holding back sub-surface (formation) pressures. It also is the non-electrolytic fluid medium in which the electric log tools are submerged so as to obtain important formation evaluation data described later.

Between the rig and the sea-bed is an assembly of equipment comprising essentially a marine riser, a blow-out preventer ("B.O.P. Stack") and a well head.

The riser is a large diameter pipe running from the rig to the sea-bed assembly and through which the drill string, casing and other in-hole equipment and tools pass. It acts as a conduit for drilling fluids from rig to hole and back. It is subject to


FLOATING DRILLING SYSTEM
CROWN BLOCK
DERRICK
TRAVELLING BLOCK
SWIVEL
KELLY
ROTARY TABLE
RISER TENSIONERS
DRAW WORKS
TELESCOPING JOINT
MARINE RISER
GUIDE WIRES
KILL LINE
CHOKE LINE
BALL JOINT
BOP STACK
GUIDE STRUCTURE
WELL HEAD
30" CASING
20" CASING
17½" OPEN HOLE
B-42547-E

lateral forces such as currents and, on floating rigs, vertical forces such as heaving of the rig. These are compensated for with tensioning lines, a telescoping joint and ball joints at each end of the riser.

The BOP Stack contains a series of remote-controlled horizontally-opposed rams and rubber elements designed either to seal the well bore running through the stack or to close around pipe or casing and seal the annular space. Pipe rams close and extrude a rubber packing to fill the annular space. Blind rams simply seal against each other when drill pipe or casing is not present. Shear rams cut through the pipe and seal the well bore.

Because of modern drilling technology a blowout is a rare occurrence. It is an uncontrolled flow of gas, oil or other well fluids into the atmosphere. It starts with a well "kick" which occurs when formation pressure exceeds the pressure applied to it by the column of drilling fluid and formation fluids enter the well bore. The blowout will be prevented if the kick is corrected by adjusting mud and formation pressure relationships.

The well head at the sea-bed serves as a point of connection between well casing and the riser-BOP assembly. It also serves as a housing from which all subsequent casing strings are hung. Because casing strings must be run progressively as the well deepens, they must reduce in size. Each string of casing runs back to the well head.

WELL SITE SURVEYING

This aspect of the work, which must be completed before the drilling rig moves onto the well site, has two principal objectives: firstly, to mark the well site and (for floating rigs which do not rely exclusively on dynamic-positioning for station-keeping) the anchoring locations; and secondly to ascertain the sea-bed profile and (for jack-ups) the subjacent soil conditions.

Well site and anchor-spread positions are located by a surveying contractor using surface surveying techniques involving multiple-point fixing. At times satellite navigation systems are used to confirm the rig's final on-site position. Buoys are positioned at these locations from the survey vessel.

The same contractor will usually carry out the necessary hydrographic survey to show the sea-bed profile and water depths at the rig site and the mooring area. For jack-ups, the profile will extend to approaches to the well site to ensure clearance for the rig legs as the rig moves onto the location.

Side-scan sonar data are also needed for jack-ups to produce a better picture of sea-bed conditions to ensure that no obstructions exist where the legs are to be positioned. Side-scan sonar data are also desirable for floating rigs working in producing fields or other areas where obstructions on the sea-bed may be expected.

The densities of strata immediately below the sea-bed are needed for jack-up rigs and at times are desirable for floaters. A "sparker" survey (a type of seismic survey) is carried out for this purpose.

Again, at jack-up locations, divers probe the sea-bed, typically to about 10 feet, and take samples to ascertain the kind of material making-up the surface layer of the sea-bed. This is important to determine, for instance, any likely scouring effects around the rig legs.

Where there is doubt as to the depth of sand at anchoring positions for floating rigs, the sea-bed may be probed by an instrument lowered from the survey vessel.

Knowledge of sea-bed conditions is often required by the rig insurer, particularly in exploratory areas.

WORK-BOATS AND TRANSPORTATION

Work-boats are used to perform all or any of three main functions.

Firstly they are used to position anchors for floating rigs. Rig cranes transfer anchors to the work-boat and winches pay-out anchor chain as the work-boat moves to each anchoring site.

Secondly they are required to tow the rig between sites. Self propelled rigs sometimes use work-boats to speed-up the move.

Thirdly they move equipment and supplies between the Operator's shore base and the rig. Items typically moved are cement (usually in bulk for offshore wells), mud and additives (some bagged, some in bulk), casing, tubing, drill bits, some contractor drill-pipe, tools, fuel and fresh water (both for consumption and to make the drilling mud).

In addition to these work-boats a stand-by vessel must be present in the operating area at all times to assist in emergencies.

One or more helicopters must be contracted for to transport personnel (and occasionally equipment) to and from the rig.

CEMENTING

A cement slurry is pumped through casing and forced up the annular space between the outside of the casing and the wall of the hole. Its purposes are to form a sheath around the casing to support and bond it to the hole and to seal off formations to prevent fluids migrating up or down the annular space.

While offshore rigs generally provide storage facilities for bulk cement, the actual cementing operation is carried out by a contractor engaged by the Operator. The contractor will furnish the pumping and associated equipment needed for this operation.

FORMATION EVALUATION

There are three main classes of operation under this category: mudlogging, wireline logging and drill stem or flow testing. In an onshore well, a further category, Production Testing, could be added. Its essential difference from a drill stem test is duration, the latter being considerably shorter offshore because of the much higher cost of keeping an off-shore rig on location; so that, as will be seen later in this commentary, the off-shore drill stem test is rarely run long enough to enable reliable reserve calculations to be made on this basis alone.

MUD LOGGING

This is the first of the services intended to reveal the presence or otherwise of hydrocarbons in the penetrated formations. It uses two sources of information: firstly cuttings and any oil they contain and secondly, gas. These are brought to the surface by the upward flow of drilling mud.

Cuttings are recovered from a shale-shaker on the rig. Samples are washed and are examined under ultra-violet light. Hydrocarbon molecules are agitated by U-V light and produce fluorescence. A "fluoroscope" or "U-V box" is used for this purpose.

Fluorescence alone may be the basis for a decision to cut and recover a core for later laboratory examination, or it may in conjunction with the electric logs be the basis for deciding to run a formation test. Sometimes the colour of the fluorescence is an indication as to whether the recovered hydrocarbons may be derived from oil.

The cuttings also furnish evidence as to the geology of the formations being drilled as well as initial indications of porosity and hence reservoir characteristics.

Any formation gas in the returning drilling mud is trapped and passed to gas detection devices of two main kinds. The first is an electrical "hot wire" detector which, within a certain temperature range, will burn methane or "dry gas". At higher temperatures propane, ethane, butane and other "wet gases" will be burnt. The ratios of wet gas to dry gas give an early indication of whether the sampled accumulation is dominantly oil or gas.

The second device is a chromatograph. This gives a more accurate and comprehensive breakdown of the components of gas in the sample. The gas is allowed to seep through an absorbent. This procedure works on the principle of different times being required for absorption of different gaseous molecules. The chromatograph functions in such a way that continuous sampling is not possible, in contrast with the hot wire method.

The entire mud logging operation will yield no significant information about economically recoverable reserves, except to show where they do not exist at all.

The "nerve centre" of this operation is the "mud logging unit", a skid-mounted or removable room. It is not normally included in the drilling rig's basic structure. Drilling contracts must allow for its positioning on the rig.

WIRELINE LOGGING

The prime purpose of wireline logging is to enable a calculation of hydro carbons in place in the immediate vicinity of the well bore. The unknowns in the equation for this calculation, and those which the wireline logging operation seeks to supply, are electrical resistivity factors for the reservoir rock and its connate water and the porosity of the rock.

Wireline logging involves passing certain sensors slowly through the well bore gathering signals which are then passed through an electric cable (wireline) to recording devices at the surface.

Electric logging measures the natural and induced electric circuits existing in the well bore from which the resistivity factors can be calculated.

Sonic logs recorded the rocks' acoustic properties from which porosity can be estimated.

Radioactivity logs record the electron and neutron densities of the rocks which enables porosity estimates to be refined. (The neutron log also enables a differentiation to be made between oil and gas in the formation.)

Another tool used in this process is a dipmeter which is designed to provide data from which the angle of intersection of bedding planes to the well bore can be calculated. From this, structural and sometimes stratigraphic interpretations can be made.

An important device often run on a wireline is a formation interval test tool. This operation consists of lowering a special chamber down the hole to a predetermined point of interest as indicated by the electric logs. Through surface controls the chamber is activated so as to make contact with the well bore, an aperture is opened and the chamber recovers a sample of the fluid or gas contained in the formation. It also records the pressure within the formation at that point.

While wireline logging will enable calculation of hydrocarbons in place in the immediate vicinity of the well bore, extrapolation of these data throughout the structure cannot be made unless the structure and stratigraphy have been accurately determined from previous geophysical, geological and/or drilling operations. Because in the case of exploratory wells such determinations cannot be made accurately, appraisal wells must be drilled to enable reserve calculations to be made.

As with mud logging, a wireline logging unit has to be installed on the rig.

FLOW TESTING

Flow testing of a reservoir rock strata is done to —

(a) Establish the type of fluid in the rock pores and sample it. This may be just to confirm other indications, or may be the only way to find out what fluids are present. Samples of water may be needed to establish chemical and electrical properties, while gas and oil samples are collected to check chemical composition (including impurities), physical properties such as waxiness of oil and to enable laboratory testing to study liquid-gas phase behaviour so that production facilities may be designed.

(b) Determine the rock permeability i.e. the ability of the rock to conduct fluid. This has economic importance for both future exploration and development. Flow rates and pressures (at surface and down the well) are measured for input to mathematical equations or for graphical techniques to determine permeability.

Flow tests during evaluation of an offshore well generally will not give any information on the size of the reservoir or reserves because the amount of oil or gas produced (withdrawn) during a short flow test (unless the reservoir is particularly small) will be too small, compared with the oil or gas in the reservoir, to provide a measurable drop in overall reservoir pressure. Tests may help locate hydrocarbon-water interfaces or show that apparently separate reservoirs are part of a larger interconnected accumulation.

Most offshore tests are conducted after steel casing has been placed in the hole and cemented in place. This pipe is perforated with jet explosives to allow flow from the rock. Steel tubing is run inside the casing and a pack-off device at the bottom of the tubing directs fluid flow up the tubing. Pressure measurement gauges can be attached to or in the tubing and other tools included in the assembly, actuated by mechanical movement or hydraulic pressure, to open and close valves to control the test sequence and provide emergency safety control. The major complication with a test on a floating rig, is the need to include an additional close-off safety valve (subsea test valve) at the blow-out-prevention stack mounted on the sea floor, and a way to disconnect all pipe above this point to allow complete vessel release quickly e.g. to ride out a cyclone.

Tools designed to compensate normal vessel up and down movement may have to be included, and depending on the test procedure, the valving and manifolding at surface may include a lubricator to allow perforating guns or measurement tools to be run inside the tubing during the test.

Fluid handling pipework on the deck of the vessel allows separation of the flow into gas, oil or condensate, and water, with appropriate measurement devices and sampling points. Restrictions (chokes) are used to change flow rates and pressures. Chemicals may need to be added or the flow stream heated up to allow proper control and operation of the surface equipment. After measurement, gas and oil are usually burnt through a specially designed misting burner(s) on the ends of booms suspended out from the vessel. Water flashes to steam at the burner, or drops to the sea.

The Operator engages a contractor to furnish test equipment (including booms and burners when these are not part of the rig inventory). This contractor also provides specially trained personnel to conduct the tests.

WELL VELOCITY SURVEYS

The depth to which an exploration well is to be drilled and the depth and thickness of the geological formations to be penetrated by the drill are predicted from regional geology and seismic sections generated by seismic surveys.

Seismic surveys allow the explorationist to map the shape of the sub-surface geological formations and from certain calculations of the seismic data derive the velocity at which sound travels through the formations thereby giving a velocity function. This function relates the travel time of sound through the formations (and time in thousandths of a second is what is measured in seismic surveys), average velocity, interval velocity and depth. Using this seismically-derived velocity function, the maps of the geological formations can be converted to depth and so the total depth of a well and tne depth and thickness of the sub-surface formations are estimated.

A more precise velocity function, and the best that can be obtained, is derived by a velocity survey conducted in a well. The determination of a velocity function from a well is necessary to correctly ascertain the average velocity to and the interval velocity of all formations. This then allows the correct correlation between the formations penetrated in the well (these are in depth) and the reflection events on a seismic section (these are in time). Thus the map showing the configuration and depth of the various formations in the sub-surface can be made more accurate than that based on the seismic data obtained prior to the well velocity survey.

The most direct procedure for velocity measurements to derive an accurate velocity function is to explode charges of dynamite or an airgun near the surface alongside a well and to record the arrival times of sound waves received by a geophone suspended in the well at a number of depths distributed between its top and bottom. This is a well velocity survey.

The interval velocity is obtained by taking the distance between successive detector positions in the well and dividing it by the difference in arrival times at the two depths after the arrival time has been corrected for angularity of the wave path. The average velocity is either the actual distance from source to receiver divided by the observed time or the vertical component of distance divided by the appropriately corrected time.

OTHER SERVICES

Diving

If the sea floor equipment could be assured of operating absolutely free of trouble, diving services would not be necessary. This of course is never the case and diving services must be on stand-by on the rig at all times except on certain rigs operating in exceptionally deep water. Even then un-manned, remote-controlled television-guided mechanical repair systems are available and are kept on the rig.

Special Tools

Frequently the operation will call for the use of tools and equipment not otherwise provided by the drilling or ancillary contractors. A common example is the diamond drilling bit. These are normally rented.

Shore Base

The Operator will need access to facilities at or near a port for storage of equipment and supplies to be taken to the rig. This may necessitate leasing the site. The operation of bulk storage equipment and stevedoring services is frequently the subject of yet another ancillary contract.

Environmental Studies and Services

Although last in this paper, this aspect of the project will need consideration early in the planning stage. The Operator or holder of the Exploration Permit may be required to furnish environmental data and otherwise comply with the provisions of the *Environmental Protection (Impact of Proposals) Act*, 1974, the *Petroleum (Submerged Lands) Act*, 1967, Exploration Permits and Directions issued under the latter act, and State or Territorial environmental legislation. The necessary governmental approval of the drilling project may be greatly delayed, and ultimately prohibited, on environmental grounds. The possibility of such delay or prohibition, and adverse consequences such as costly stand-by payments for the rig and ancillary services and perhaps the inability to meet Permit work obligations on time, render it essential to address environmental issues early. In terms of ancillary contracts, this may result in the retention of environmental consultants and possibly the procurement, whether direct or via a contractor, of oil-spill containment, clean-up and dispersal equipment.

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