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GUIDE TO EXPLORATION FOR AND EXPLOITATION OF NATURAL OIL AND GAS RESOURCES OF THE MEDITERRANEAN SEA AND BED

With Glossary of terms in common use

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P R E F A C E

This document has been prepared at the request of the Co-ordinating Unit for the Mediterranean Action Plan. Its purpose is to serve as a brief and simple guide for those who have as yet no technical knowledge of offshore operations for oil and gas, nor scientific knowledge of their possible consequences for the marine environment, but who may be called upon to play a part in the making of a new decisions on the protection of the Mediterranean Sea against pollution from such operations.

An attempt has been made to keep this guide as brief as possible, without slipping into inaccuracy, and without omitting details which are of sufficient significance in the problem of pollution control to merit the attention of those deciding what forms of control may be needed. Beyond that point much detail has necessarily been omitted.

The guide is intended to serve a further purpose. It seeks to explain to the 'layman' in ordinary language the technical and scientific terms he may meet in the literature and in discussion and even the jargon which may unfortunately be thrust upon him. For easy reference to the meanings of those terms there is a glossary. It includes some which do not appear in the text because they refer to matters considered too detailed or too technical for simple guide.

Each of the pollution problems referred to in this paper will of course be examined in greater detail at later stages in the work.

The account includes only statements which, it is hoped, can be accepted as non-controversial. For that reason, and to keep the text simple and uncluttered, sources of information have not been cited. The author wishes to acknowledge, however, the help he gained from the papers originally written for the I.J.O. and U.N.E.P.

by Mr C.P. Garner-Richards and by Mr W.H. Berry, on exploration and exploitation, and on the design and construction of pipelines respectively. He also wishes to thank the United Kingdom Offshore Operators Association, Mr A D Read of E & P Forum, and Agip of Italy for various publications, and permission to use the maps and diagrams provided therewith. Finally he wishes to thank the wide range of people he consulted individually on specific matters.

Nevertheless, the author accepts full responsibility for the account as it stands, with any errors therein or significant omissions therefrom.

PART ICONCESSION AREAS

The maps below show the areas of the Mediterranean Sea bed where concessions for exploration for or exploitation of oil and gas have already been granted. The fact that an area is so marked does not mean that any drilling has been done therein. (For the maps see pages)

PART II OFFSHORE OPERATIONS FOR THE DISCOVERY,
EXTRACTION AND TRANSPORT TO SHORE OF
OIL AND GAS

1. NATURAL SUBTERRANEAN ACCUMULATIONS OF OIL
AND GAS.

1.1. Oil, together with the gas which normally accompanies it, is thought to have been formed by the decomposition of organic matter from animals and plants which lived in past ages. Due to difference in pressures, gravity and permeability, it will often have moved from the area of formation. Some has reached the surface of land to form natural seeps either ashore, or from the sea bed as off Trinidad and California. Much, however, has been trapped by impervious layers, to lie in the interstices of porous rock, often at high pressures.

1.2. In such a trap there is usually gas, oil and water which tend to separate into three layers, the lighter fluids naturally moving upwards.

There are also usually impurities, including sulphur compounds. Some form sulphur dioxide when the oil is burned as a fuel, which can contribute to acid rain in the atmosphere. Oil with a low sulphur content is consequently in demand. The sulphur can also form hydrogen sulphide in the formation. This can escape during exploration or the extraction process, and be a grave danger to those engaged in the operation.

1.3 The hydrocarbon gases found with oil, which include methane and others of more complex chemical structure, are extracted to be sold as fuel when found in sufficient quantities for that to be

commercially worthwhile. Being highly inflammable, and explosive in confined spaces, they can constitute a danger to operators, and could destroy plant and equipment thus releasing large quantities of oil. Otherwise, however, in themselves they present no pollution problem. For that reason, except when the presence of such gas itself presents a problem, the remainder of the paper will be in terms of oil. It must be remembered, however, that some gas is invariably present, and will have to be separated from the oil.

2. EXPLORATION

2.1. Surveys

- 2.1.1. The first step in exploration is a study of the geology of the area. If that study indicates the possibility of the presence of oil bearing strata, surveys may be undertaken.

2.1.2. Magnetometer Surveys

These are surveys which measure variation in the earth's magnetic field. They are made from the air and cause no pollution or risk of pollution.

2.1.3. Gravimetric Surveys

These are surveys which measure variations in the earth's gravity. They are made from ships, and likewise present no pollution problems.

2.1.4. Seismic Surveys

A seismic survey is carried out by sending shock waves through the strata, where they are deflected by any discontinuity. In the past the shocks were caused by explosions. Today a shock or "pulse" is created by the release of compressed gas from equipment aboard a ship. Any deflection is received and recorded by a geophone or a hydrophone, towed behind the vessel. The timing and analysis of the vibrations received by the instrument can give information about the strata beneath the sea bed.

Now that compressed gas is used, it is claimed that no significant damage is caused.

2.2. Exploratory Drilling

- 2.2.1 Such surveys can only show that accumulations of oil or gas may exist in those strata. To prove its

existence there must be exploratory drilling. a hole or "well" is drilled into the strata where it is believed they may be held. (The process of that drilling is explained in 3.6.). Any resulting discharge of oil or gas will be examined, and the pressure at which it is held in the formation estimated. Even if there is no discharge from the well, the presence of oil may be detected by an examination of drill cuttings (see 3.6.3.).

- 2.2.2. If that proves the presence of oil which can be successfully extracted, further work needs to be done to assess the extent of the oil bearing strata, and the quantity of oil available. Only then can the operator decide whether or not to proceed with exploitation. That is done by drilling further "appraisal wells", sometimes called "step-out wells".
- 2.2.3. If there appears to be no oil or gas present, or insufficient to make extraction commercially worthwhile, the well or wells are plugged with cement to a depth considered sufficient to ensure safe and permanent closure. The State which granted the licence may specify or approve the depth. When oil has been found in commercially worthwhile quantities, development work will follow, (see Section 4) or the well will be temporarily plugged to form a "suspended well head" which will remain awaiting exploitation, (see also 4.8.3.)

3. THE DRILLING PROCESS

3.1. It is convenient to deal with the drilling process for whatever purpose it may be used, for it may be done as part of exploration or appraisal, or done to sink wells for the purpose of production. Even after production has started, further wells may be drilled either for the extraction of oil or injection of water, (see 4.6.1.), and existing wells may be diverted.

3.2. Types of Drilling units

3.2.1. Drilling for exploration or appraisal will normally be done from one of three types of plant or vessels, known compendiously as "mobile drilling units." They are jack-up rigs, semi-submersible rigs, and drill ships. Drilling for production is sometimes done from a fixed production platform.

3.2.2. Jack-up Drilling Rigs

A jack-up rig is basically a 'barge' to which there are fitted legs which can be raised or lowered vertically by means of hydraulic jacking or rack and pinion (see Fig 1). With its legs raised it can be towed, or carried on a very large ocean going barge, to its location for drilling. There its legs are lowered until it stands on the sea bed with its deck clear of the water. They are suitable for drilling in waters with a depth of down to 90 metres.

3.2.3. Semi-Submersible Drilling Rigs

A semi-submersible rig is basically a deck standing on fixed legs which in turn stand on large buoyancy tanks, (see Fig 1). It can be towed to its location or, if it is self propelled, travel there under its own power. Once there it is anchored, its tanks take in water until they submerge sufficiently to leave the deck clear of the water.

The rig is held in position by cables attached to the sea bed, the cables extending out in some cases to 1,500 metres from it. Any tendency to sideways movement can be controlled by winches operating on the cables. It can drill in waters as deep as 300 metres or more.

Such rigs can now be fitted with "dynamic positioning" equipment, (see 3.2.4.).

3.2.4. Drill Ship

A drill ship has a large hole in the hull called a "moonpool" through which drilling is done, (see Fig. 1.). Earlier designs were anchored in position, but some now have "dynamic positioning". This is done by propellers pointing in different directions. They are controlled by computers which respond to the pressures of wave and currents to keep the ship in one position whilst drilling is in progress.

Some modern drill ships can operate in water depths down to 1,500 metres,

- 3.2.5. An earlier type of mobile unit, the submersible drilling rig, simply sat on the sea bed in shallow waters. That type is now little used.

3.2.6. Fixed Platforms

Production platforms are large structures made of steel and pinned to the sea bed, or made of concrete and resting on the sea bed, (see 4.2.). Many now carry their own drilling equipment, which can be used for drilling new production wells, or diverting existing wells.

3.3. Stand-By Vessels

Many rigs have "stand-by vessels" permanently nearby in case of emergency. Some States make it

a legal obligation to have them (c.f. 4.3.).

3.4. Safety zones

Both the Convention on the Continental Shelf 1958 and the United Nations Convention on the Law of the Sea 1982 provide that the coastal State may establish a safety zone around each installation extending to a distance of 500 metres therefrom. The purpose of the zone is to prevent collisions between surface vessels and the installation. Ships are therefore not allowed to enter the zone, an exception being made for the stand-by vessel.

3.5. Certification

Drilling rigs are normally subject to certification in the same way as production platforms (see 4.5.).

3.6 Presence of Drilling Rigs and Possible Effects on Navigation and Fishing

The possible effects of the presence of rigs on navigation and fishing are considered in 4.8.

3.7 Drilling a Well

3.7.1 For drilling, a bit is attached to the end of a steel pipe. Bits vary according to the diameter of the hole needed and the kinds of strata through which they have to drill. They can be thirty-six inches in diameter and usually have toothed wheels which bite into the subsoil to be drilled. The steel pipe is narrower than the bit, thus leaving a space between the pipe and the wall of the well, known as the "well annulus".

The whole is turned by a power driven "rotary table" on the drilling deck. As the well is driven deeper, new sections of pipe are added. The whole length of

pipng from rotary table to bit is called the "drill string". It can extend to a length of 20,000 ft.

A steel lining known as a "casing" is put into the upper parts of the well to support and seal the walls. The depth to which casing is to be inserted is a matter for careful judgement. As the drill goes deeper, smaller bits are fitted, making a well which goes narrower by stages. A typical well may be 30 inches in diameter at the upper section, reducing by stages to seven inches. The rate progress in drilling varies from about one to 200 feet per hour according to the strata being drilled.

- 3.7.2. During drilling a special fluid called a "drilling fluid", or more colloquially a "drilling mud" is pumped down the centre of the drill string. (For further details on these fluids see 3.8.) This passes through the bit then travels back up the well annulus. In doing so it serves several purposes.
- (a) It cools, and may lubricate, the bit.
 - (b) It carries the drill cuttings to the surface.
 - (c) It can seal the surface of the well wall to prevent crumbling, entry of fluids from porous strata through which the well passes, or escape of gas or oil into such strata.
 - (d) The weight of the long column of drilling mud can counterbalance upward pressure of oil when a stratum where it is held at high pressure is penetrated.

The muds are also "thixotropic", which means that they are fluid when stirred or moved, but gel when stationary. Consequently, when pumping stops the mud will gel to hold the cuttings in suspension and support the wall of the well.

- 3.7.3. When the drilling mud returns to the surface it is passed through sieves called "shale shakers".

There the drill cuttings are removed, and the mud can be recirculated. Periodically a sample of cuttings is sent to the geologist aboard the rig. This enables him to chart the strata through which the drill has passed.

- 3.7.4. It is now possible to drill by means of "turbo drills" or "mud turbines". In that kind of drilling the pressure of the mud is used to drive the bit.

3.8. Drilling muds, Drill Cuttings, and Environmental Damage

- 3.8.1. A drilling mud consists of particles held in suspension either in water or oil and water. Most of the particles are inert substances such as bentonites which assist in gelling, and weighting agents such as barytes. Other substances are added for special purposes, e.g. seal the wall of the well, control the flow properties, inhibit corrosion, kill bacteria. The composition of the mud will be changed to meet the demands of changing circumstances, e.g. further weighting agents added if higher well pressures are felt or anticipated. The chemistry of drilling muds is complex, and of considerable importance to those engaged in drilling.

- 3.8.2. Water based drilling muds are frequently used. In some cases, however, they are considered unsatisfactory, and oil based muds are used instead. The early oil based muds used diesel oil, which can be toxic to marine life. Muds based on refined mineral oil, often referred to as "low toxicity muds" are now available. They are normally preferred by the State authorities because they have a much lower toxicity, but operators still consider it necessary to use diesel based muds in some circumstances.

- 3.8.3. Drill cuttings may be extracted at a rate of up to 350 tons in 24 hours. Those raised by water based muds are usually dumped on the sea bed below the rig or platform. They will smother any benthic organisms living there, and toxic effects can be detected for a distance of about 500 metres. Cuttings raised by diesel based muds can have effects on benthic organisms to a distance of 3,000 metres. Such drill cuttings are sometimes washed before deposit, but washing is rarely completely successful, particularly where the cuttings have become impregnated by the diesel oil at high pressures.
- 3.8.4. The drilling muds themselves must eventually be discarded. Water based muds discharged to the sea will do little damage, except when toxic chemicals such as biocides have been added to them. Diesel based muds are considered too toxic for discharge, and the operators normally required to take them ashore for disposal.
- 3.9. Risk of Blow-Out, and Safeguards against that Risk
- 3.9.1 The pressures at which oil is held below ground usually increases with depth. An approximate relationship of 435 p.s.i. per 100 feet has been established for these normal "formation pressures". Abnormally high pressures, however, known as "geopressures" are sometimes found. If the drill penetrates such a high pressure pocket, there may be a "kick back" of exceptional pressure felt at the well head. Special equipment is installed, and special procedures are used to withstand such sudden kicks. If they fail to do so, the oil or gas bursts from the well in an uncontrolled surge known as a "blow-out".
- 3.9.2. The first precaution in preventing a blow-out is to anticipate the kick back if possible. This can sometimes be done, partly by accurate prediction of

the strata and conditions which will be found below the surface, partly from monitoring progress, and partly from data from and experience with other wells in the area. An experienced driller who can anticipate a kick back can then take steps to counter it, e.g. by changing to a heavier drilling mud. It is therefore important to have properly trained and experienced people in charge of drilling. It is also important to have a trained crew who can respond quickly and effectively in an emergency.

- 3.9.3. If a kick back occurs which cannot be counter-balanced by the drilling mud then in use, control may be maintained or re-established by use of the blow-out preventer. That is a piece of equipment fixed on the sea bed at the well head, or in the case of jack up rigs and platforms, aboard the installation.

The blow-out preventer contains an annular valve and several sets of rams, offering options according to the severity of the kick back, (see Fig 2). The annular valve, or "hydril", is used to contain the less severe kicks. It closes round the drill pipe, thus shutting off the well annulus but permitting heavier muds to be pumped down to restore the balance of pressures. To hold more severe kicks "pipe rams" may be operated. These are hydraulically operated rams which again close around the drill pipe. Finally "blind rams" or "shear rams" may be operated. The former are used when the drill string is out of the well, the latter used to crush the drill string when it is in place. Both close off the well completely, a measure the driller seeks to avoid, for there is little else he can then do.

Should all those measures fail, a blow out occurs, and a specialist team may have to be called in to handle the crisis.

The initial blow-out may be an explosive event, and then or subsequently the escaping gases may catch fire. There is then serious danger to the crew, the installation will have to be abandoned, and may be completely destroyed. In less serious blow-outs the wall of the well may crumble inwards, with pieces of rock "bridging" the hole and eventually forming a blockage which prevents further escape. Conversely the fluids may force their way through breaks in the wall of the well to reach the surface through fissures in the rock at points away from the well head itself. That renders the blow-out much more difficult to bring under control.

If the flow cannot be stemmed at the well head, another rig may be called in to drill a "relief well". This may penetrate the subterranean reservoir close to the original well, or even penetrate the original well itself. Measures can then be taken such as pumping in concrete to block the flow. Because it may take a long time for another rig to reach the location, this possible need must be anticipated well in advance.

- 3.9.5. Even with the best available technology, the risk of a blow-out cannot be eliminated completely. There remains some element of risk inherent in the operation itself. The risk varies according to the area in which the drilling is done. Estimates based on U S offshore activity have shown a risk for mobile drilling units of one blow-out for every 500 wells drilled. The consequences also vary, from blow-outs in the North Sea with no significant damage, to the Ixtoc blow-out in the Gulf of Mexico which lasted from 3 June 1979 to 24 March 1980 with about 400,000 tonnes of oil lost and extensive damage done. Much of the oil burned in the fire which started above the well head, otherwise the pollution damage might have been greater than it was.

3.10

Illegal Disposals

Illegal disposals are dealt with at 4.12.

4

PRODUCTION

- 4.1 For the purposes of this paper "production " means bringing the oil to the surface and separating it from the gases and the water with which it is invariably mixed on arrival. It may be transported to shore and taken to a refinery as crude oil, although there is still some water mixed with it which must be separated off.

The initial separation of oil, gas and water is usually done offshore at the platform, although the oil and water may be piped ashore together for separation there.

The gas is always separated off at the platform. If found in commercially useful quantities, it is either taken ashore, or pumped back into the formation for storage. Smaller quantities may simply be flared off at the platform.

4.2. Types of Offshore Production Installations

- 4.2.1. There are various types of offshore production installations, and as exploration is extended to the new regions and technology is improved, there will doubtless be more. Seven are described here, and illustrated in Figures 3 and 4.

4.2.2. Steel Production Platform

This comprises a steel, towerlike structure, sometimes referred to as a "jacket", and a series of decks built thereon and fitted with the necessary plant and equipment.

The jacket is constructed ashore, floated out to the chosen location, then fixed there by piles driven through its members into the sea bed. All other fittings are then added. (See Fig 3)

Underwater sections usually carry sacrificial anodes to inhibit corrosion of the main structure. (See 4.10.2. and glossary).

4.2.3. Concrete Production Platforms

A concrete caisson is built on a steel base, and a concrete superstructure of one to four cylindrical columns added. The whole is then floated out to its location, where it sits on the sea bed held down by its own weight. Finally decks and the necessary plant and equipment are fitted. A level sea bed, firm enough to support a weight of up to a half a million tons is needed for the site. (See Fig 3)

Hollow parts of the concrete structure are used for storage of oil.

4.2.4. Sea Bed Completions

Instead of a platform immediately over the sea bed, there may be a "sea bed completion", sometimes referred to as a "sub-sea completion". This usually comprises control valves contained in a strong steel cage, (see Figs 4 & 5). From there the well product may be piped to a simple type of platform, or even to a tanker fitted to perform the remaining functions of a production platform. Moreover, a normal platform, extracting from wells over which it sits, may be served also by a satellite sub-sea completions. A different form of sub-sea completion is sometimes used over a water injection well.

4.2.5. Floating Production Platforms

These are semi-submersible vessels, anchored to the sea bed by cables in the same way as a semi-submersible drilling rig. (See 3.2.3. For illustration see Fig 3).

4.2.6. Guyed Tower

This is a lightweight steel tower. It has built in buoyancy and is anchored to the sea bed by cables, (see Fig 4).

4.2.7. Tension Leg Platform

This is a floating production platform tethered to the sea bed by a number of steel tubes. Tension is maintained between that anchorage and the buoyancy of the platform. It can be used in water depths of over 300 metres.

4.2.8. Production Ship

This is a tanker like vessel with a moon-pool through which it receives the well product from a sub-sea well head. It can be used for fields of marginal commercial value, where the cost of a fixed platform may not be justified.

4.3. Stand-By Vessels

Many manned platforms have stand-by vessels permanently nearby, principally for use in emergency. In some States there is a legal obligation to have them, (c.f. 3.3.).

4.4. Safety zones

The safety zones referred to in 3.4. are normally established round production installations.

4.5. Certification of installations

4.5.1. Care in design, construction and stability of installations is of the greatest importance. Such care is needed primarily, of course, for the protection of human life. In this context, however,

it is relevant to note that lack of such care can also lead to extensive environmental damage.

- 4.5.2. For those reasons it is an established practice to require that an installation be certified by a body, independent of both operator and manufacturer, that is is safe and fit for the purpose. Additionally, for an installation which rests on the sea bed, it is considered necessary to ensure that it has a sufficiently firm foundation to remain stable.
- 4.5.3. Examinations are carried out, and certificates granted, by independent experienced bodies such as Lloyds' Shipping Register, the American Bureau of Shipping and Det Norske Veritas.
- 4.5.4. It is first necessary to establish criteria and standards on the basis of which certificates may be granted. Such codes of criteria and standards have been drafted by the principal certifying authorities for various types of installations. The International Maritime Organisation also published a "Code for the Construction and Equipment of Mobile Offshore Drilling Units". (The MODU Code). This recommends "design criteria, construction standards and other safety measures so as to minimise the risk to such units, to the personnel on board and to the environment."
- 4.5.5. National legislation itself may lay down minimum criteria and standards. United Kingdom and Norwegian legislation list the environmental factors which must be taken into account, e.g. wind waves, current, ice and snow. The former requires that the values for those factors shall not be less than those "exceeded on an average once in any period of 50 years," whilst the latter requires each to be the "largest value in a period of 100 years". Other legislation relies on what is "foreseeable" or "can be expected".

4.6 The Offshore Production Process

4.6.1. Extraction

After exploratory wells and appraisal wells have been drilled, and a decision made to extract the available oil, (see 2.2.2.), further wells are drilled so that as much of the oil as economically possible may be extracted. Some may be satellite wells served by sub-sea completions (see 4.2.4.), but many, up to 48, may be drilled under the principal platform itself. This is possible because the driller can drill wells which follow a curved line, and which may deviate from the vertical by 60° . In this way the wells can be splayed out to penetrate the reservoirs of oil at various points, (see Fig 8). A drill may even be directed to an isolated pocket of oil over a mile from the site of the platform.

The wells are lined with steel casing which supports and seals the walls. That casing may go to the top of the oil bearing formation, or may penetrate it. In the latter case holes will then be made in it by 'guns' lowered on cables and electrically fired. The oil is thence conducted to the surface in a smaller diameter pipe, known as "production tubing".

Usually the pressure in the formation is sufficient to drive the oil up to the well head. As oil is extracted, however, that pressure will decrease. Water or gas is then pumped into the formation down a separate well to increase the pressure. In the later stages about 30% of the fluid reaching the well head may be water, much of which is injection water returning.

Not all the oil can be extracted, and further methods already used onshore are being considered.

The performance of each well is continuously monitored on the platform, with computer terminals in the control room showing such factors as flow rate, pressure, temperature, water content, gas content.

4.6.2. Control, Separation and Distribution

On the platform, or at the well head in the case of a sub-sea completion, the tubing leads to a set of pipes and valves, known by reason of its shape as a "Christmas tree", (see Fig 6). This controls the flow from the well, and distributes it to plant where the oil, gas and water can be separated.

After separation, the oil passes into a pipeline to shore, or is passed to storage tanks to await transport to shore by tanker. The gas is taken ashore to be sold as a fuel, pumped back into the formation to be stored for future use, or is flared off at the platform if it is found in only small quantities. The water, which is still contaminated with oil goes to oil and water separators, from which it emerges less heavily contaminated to be discharged to the sea. The oily residues in the separators are taken ashore for disposal. Alternatively, the water may be pumped back into the formation as injection water, (see 4.6.1.).

On some platforms, the gas only is separated off, the oil and water being piped to shore for separation there.

4.7 Safety Devices on Production Platforms

4.7.1. Before production commences, certain devices are installed to control the flow from the well and to prevent a blow-out. They are as follows.

4.7.2. Packer

Once drilling has ceased, the drill string is withdrawn and production tubing inserted to carry the oil to the surface. The surrounding space, still called the "well annulus", must then be closed. This is done by inserting a special plug called a "packer" to seal that space. A column of non-corrosive mud is then injected to sit above it and provide added resistance to any upward thrust. (See Fig 5). It is usually referred to as the "annulus fluid".

4.7.3. Christmas Tree

During normal working, control is maintained by means of the Christmas Tree, (see 4.6.2. and Fig 6). As can be seen from Figure 6 this contains gauges and valves connected with all parts of the system.

4.7.4. Surface Valves

Additionally, there is a valve normally found downstream of the master valve of the Christmas tree to shut the well automatically if either pressure or temperature rises to a level which is unsafe. There are also other safety valves further downstream to protect particular parts of the production system.

4.7.5. Sub-Surface Safety Valve

Finally, there is a "sub-surface safety valve" which lies in the production tubing below the level of the sea bed, (see Fig 7). The most important characteristic of this device is that it is held open by hydraulic pressure through a line from the platform. When the hydraulic pressure is released, the valve closes. This means that not only can it

be closed manually as the need arises, but if there is an accident causing serious damage to the well head equipment, pressure is lost and the valve automatically closes, thus stopping the flow of the oil.

4.8 Presence of Installations and Possible Effects on Navigation and Fishing

4.8.1. In considering the possible effects on navigation and fishing, it is convenient to deal with exploration, production and transport together.

4.8.2. Exploration

Rigs stay in one area for exploratory drilling for relatively short periods. Given proper notification, and adequate lights and other warning devices, they will constitute no long term hindrance to navigation or fishing. Even in the short term, serious hindrance to navigation is unlikely.

There can, however, be some temporary interference with fishing. The cables holding a semi-submersible rig in position may extend for 1,500 metres from the rig, well beyond the 500 metre safety zone. Those cables may catch the trawls of fishing vessels. Trawlers therefore tend to give them a very wide berth, thus losing access to that sea area.

4.8.3. Production

The effects of the presence of production platforms are more widespread, and longer lasting. Widespread because the installations are often placed in clusters, especially if satellite wells are used. Longer lasting because they may remain in place for many years. For a diagram of a cluster see Fig 8).

A cluster of surface installations on or near a

shipping route can be a hindrance and an additional hazard. The I.M.O. recognises this and has made recommendations on leaving fairways for shipping.

A cluster can also seal off from fishermen a wide area of sea, especially for trawlermen who dare not risk taking their trawls between them. This tendency increases as the practice of having satellite wells grows; for sub-sea completions, (see 4.2.4), although marked by buoys, can be just as much a hindrance to fishermen. The same is true of suspended well heads, (see 2.2.3.)

Finally, it may be noted that floating production platforms, (see 4.2.5.), having cables to hold them in position, present the same hazards as semi-submersible rigs, (see 4.8.2.).

4.8.4. Pipelines

This is dealt with at 5.1.5.

4.9. Waste Waters from the Production Process

4.9.1. Production Water (Produced Water)

This is the water separated from the oil after it has emerged from the well. It can come from two sources. Some is water which was trapped in the formation with the oil and is referred to as "formation water", (see 1.2) Any other water will be injection water, (see 4.6.1.)

The proportion of produced water varies naturally from one field to another. Amounts of injection water also vary, tending to increase as the well becomes exhausted. The total of production water can consequently vary considerably, and be a large proportion of the fluid emerging from a well.

Once separated off, the degree of contamination of production water can also vary. Produced water may have dissolved some of the constituents of the oil when that was under high pressure in the formation, and can also be very saline.

The water is usually put through oil and water separators on the platform. It is generally accepted that normally the oil content can thus be reduced to 40 p.p.m. when measured as a monthly average. Alternatively, as noted in 4.6.2., it can be piped ashore still mixed with the oil.

4.9.2. Displacement Water

At or near some platforms the oil from the well is stored in containers awaiting transport to shore. These are usually in the form of vertical cylinders to which sea water is admitted from the bottom as oil is pumped out to tankers, and from which that water is forced out as fresh oil enters from the well. The water forced out has become contaminated with oil. It is treated and discharged to the sea. The oil content on discharge is usually little more than 10 p.p.m.

On a few platforms, gas is separated from the well product, the remaining fluid then sent to storage vessels which likewise work on a displacement system. The production water settles out there. The 'water' from those tanks, which goes for treatment before discharge, can thus be as much production water as displacement water.

4.9.3. Offshore Processing Drainage

This is drainage from the decks of the modules where the oil and water separating processes are housed. It is small in quantity but can be heavily contaminated.

4.9.4. Machinery Space Drainage

This is drainage from areas on the platform where machinery is used. It is from lubricating oils, leaks and spillages. The quantities are small.

The International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978, to some extent governs platforms as well as ships. It requires that in certain special areas, of which the whole of the Mediterranean is one, machinery space drainage shall not be discharged to the sea unless the oil content is no greater than 15 p.p.m. Being of small quantities, it can simply be transported to shore as an alternative to treatment and discharge.

4.9.5. Sewage

There is the sewage that is inevitably produced in all living quarters.

4.9.6. General Garbage

It is usual to collect garbage for transport to shore. Thrown overboard, much of the non-degradable content would remain floating on the surface.

4.10. Chemicals used in the Production Process

4.10.1. Various chemicals which can get into the environment are used in the production process. Classified according to function, the main ones are as follows.

(a) Scale inhibitors

Used mostly to protect pipework and surface equipment. May get into the marine environment.

LC/50 - c 5,000 p.p.m.

(b) Corrosion inhibitors

Injected into flow lines, well etc. May get into the marine environment via production water.

LC/50 - 20 to 200 p.p.m.

(c) Biocides

Use similar to corrosion inhibitors. May get into the marine environment, again via production water.

LC/50 - 1 p.p.m.

(d) Demulsifiers

Injected into the Christmas tree to facilitate separation of water from the product. Tend to stay with the crude, but can get into production water in small quantities. No inherent toxicity.

(e) Pour point depressant

As for demulsifiers. Tend to stay with the crude.

(f) Oxygen scavengers

Prevent corrosion in the pipeline.
Non-toxic.

- 4.10.2 Sacrificial anodes (see glossary) also contain pollutants which may get into the marine environment, e.g. mercury, lead, cadmium.

4.11. Risks of Accidental Pollution from the Production Process

4.11.1 Escape of Gas

An escape of gas is unlikely to cause pollution of the marine environment directly, but may affect personnel, or cause fire or explosion.

Some of the gases which may escape are highly inflammable, others such as hydrogen sulphide are toxic. The latter may derive from the formation, where it was produced naturally or

it may have been produced by bacterial action down the well. It may also be formed beneath the platform as a result of sewage disposal, and have a corrosive effect on the metal legs.

All platforms have automatic warning systems for fire and hydrogen sulphide. Every platform also has a flare, burning at all times, where unwanted gases still under control can be burned.

4.11.2 Blow-out

There can be a blow-out from a production well, although they occur far less frequently than during drilling. It has been estimated that they occur once in every 3,200 well years. A well in that estimate means one drill hole, of which there are several under each production platform, (see 4.6.1.).

The time of greatest risk is during a "workover", when production from the well is stopped, and major works of maintenance, repair or modification are carried out. Periodic maintenance of well head equipment is needed, and repairs or changes may be needed down the well.

In a major workover the well is "killed", i.e. the flow from it is stopped, by first pumping in drilling mud, then closing the sub-surface safety valve and sometimes inserting plugs in the production tubing. Thereafter the Christmas tree can be removed and replaced by a blow-out preventer stack. The necessary work can then be done, lowering instruments down the well if necessary.

Workovers are normally carried out by specialist teams, not by the regular operating staff on the platform.

4.12 Illegal Disposals

There is always a risk of illegal disposals, whether negligent or deliberate. A workman may throw overboard a small quantity of waste oil, or a piece of broken equipment. Debris lying on the sea bed can be a hazard for fishermen.

Because of this risk the provision of a ready means of proper disposal is important. This applies to rigs as it does to platforms.

5. STORAGE AND TRANSPORT TO SHORE

5.1. Transport by Pipeline

5.1.1. Given suitable circumstances, transport to shore by pipeline is environmentally the safest method. For that reason, the State having jurisdiction in the area may insist on a pipeline, and even joint use of a pipeline by different operators. If the decision is left to the operator, cost will clearly be the overriding consideration.

5.1.2. The circumstances referred to above include the following.

- (a) Contours of the sea bed.
- (b) Composition of the sea bed.
- (c) Absence of outcrops of rock or other obstructions or hazards, e.g. dumped explosives.
- (d) Tidal flows and frequency and ferocity of storms. Possible effects of currents, e.g. scouring which could expose a pipe originally buried. Stability of the sea bed, e.g. absence of moving sand waves.
- (e) Possibility of fouling by ships anchors or fishing trawls.

5.1.2. The pipe itself may be a welded seam steel pipe, although a seamless or a flexible pipe may be used. It is connected to the oil source on the platform by means of a vertical "riser" attached to the jacket of the installation and specially protected against both corrosion and impact.

There are codes laying down safety standards for pipelines, as there are for other installations (see 4.5.4.) and the State may itself lay down standards.

5.1.3. The pipeline will be given an anti-corrosive coating, and further protection against corrosion will be given by sacrificial anodes or an impressed current system, (see the glossary for an explanation of these terms). It is then given a coating of cement mixed with other substances in order to give it additional weight and hence stability on the sea bed. The thickness of this "weight coating" will vary according to the sea bed conditions in that area.

5.1.4. For much, but not necessarily all, of its length the pipe will be buried. A trench is first made. This is done by high pressure water jets or by "airlifting" where the sea bed is soft. In heavy clays dredging may be used, and on a rocky sea bed blasting. After the pipe has been laid in the trench it may be left to be covered by natural back-fill, but in some conditions of tides and currents heavier materials may be dumped on it to provide a more stable fill. There is some evidence that materials that are themselves polluting, e.g. slag from iron works, have been used for this purpose.

5.1.5. Environmental Hazards Created by Pipelines

The risk of the most extensive environmental pollution lies in the possible fracture of a pipeline. This could happen if a ship anchor caught and pulled it; and could happen even at a place where the pipe was originally buried if the scouring action of currents had subsequently exposed it.

There are safeguards. The line of the pipe should be marked on navigation maps. The Convention on the High Seas 1958, which still applies to seas beyond territorial waters, provides another safeguard. State parties are required to pass

legislation to ensure that the owner of a ship which sacrifices an anchor or fishing gear to prevent damage to a pipeline shall be entitled to be indemnified by the owner of the pipeline. The United Nations Convention on the Law of the Sea contains a similar provision.

The operator also normally installs a mechanism to cut off the flow of oil automatically in the event of a fracture. This operates on a fall in oil pressure in the pipe, or a sudden difference between the outflow at the shore and inflow at the platform. One disadvantage, however, is that those systems have a built in tolerance so that they will not be triggered by every minor shock or disturbance. Unfortunately they are then not triggered by a minor leak, which may continue for some time before discovery.

There is some conflict of opinion, and consequent doubt, whether the presence of a pipeline constitutes a hindrance to fishing. This is a matter which merits further investigation.

5.2. Storage at or near the Well Head

- 5.2.1. One disadvantage of transport to shore by tanker is that oil must be stored at or near the well head, otherwise the flow from the well would have to be stopped whenever there was no tanker loading.

The storage facilities used vary from the large storage chambers in concrete platforms or smaller storage chambers at steel platforms, to a tanker or a very large buoy permanently moored at a safe distance from the platform and connected to it by pipeline, (These types of buoys are briefly described in 5.3.3.).

5.3. Transport to Shore by Tanker

- 5.3.1. Transport to shore by tanker is regarded as involving more risks of pollution than the use of a pipeline. There is a real risk of small spillages in loading and unloading, and there is always some risk of collision.
- 5.3.2. For safety, loading is done at a buoy, often about a mile from the platform, but connected to it by pipeline. The larger buoys which have been developed for this purpose are known as "single buoy moorings", (S.B.M's). These are very large buoys, securely tethered to the sea bed, at which a tanker can moor and safely swing round throughout 360° so as to keep its head to the weather. It takes on oil from the buoy through flexible pipe.
- 5.3.3. In a very exposed location, an "exposed location single buoy mooring" (E.L.S.B.M.) may be used. This is in the form of a huge vertical cylinder, known as a "spar buoy". It has a powered turntable to align its mooring and loading equipment with the tanker, and may contain within itself a large storage capacity, (see Fig 9).

6. ABANDONMENT OF INSTALLATIONS

- 6.1. When an installation such as a platform, pipeline or sub-sea completion is no longer used, unless it is completely removed it can constitute a hindrance to fishing or other lawful uses of the sea, and therefore be a form of pollution with the definition given in the Barcelona Convention.
- 6.2. The Convention on the Continental Shelf 1958 states that "Any installations which are abandoned or disused must be completely removed." The United Nations Convention on the Law of the Sea, on the other hand, in the part on exclusive economic zones states,
"Any installations or structures which are abandoned or disused shall be removed to ensure safety of navigation, taking into account any generally accepted international standards established in this regard by the competent international organisation. Such removal shall also have due regard to fishing, the protection of the marine environment and the rights and duties of other States."
- 6.3. Although the Convention on the Law of the Sea is not yet in force, its provisions are already accepted as a guide to future conduct. Whether a part of a platform left on the sea bed is likely to be a danger to navigation or a hindrance to shipping will be a question for the State having jurisdiction to answer, and its decision on removal will depend on any standards established by the I.M.O.
- 6.4. It may be said of a pipeline that it was no hazard or hindrance when in use, therefore it will not be when disused. Once abandoned, however, no-one remains responsible for proper maintenance, and in course of time it may be exposed as a result of tidal actions or currents.

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GLOSSARY

- Air lifting - jet of compressed air directed at the surface of the sea bed to lift out the soil and form a trench. (5.1.4)
- annulus - the space separating the drill string in drilling, and the production tube during, from the casing or wall of the well. (3.7.1 and 4.7.2. See also Fig 5 & 6)
- annulus fluid - the fluid used to fill the annulus during production. (4.7.2. See also Fig 5)
- appraisal well - well drilled to assess the extent and capacity of an oil bearing formation.
- barrel - standard measure for crude oil, equal to 159 litres or 35 imperial gallons.
- barytes - a form of naturally occurring barium sulphate used as a weighting agent in drilling muds. (3.8.1)
- benthic - benthic organisms are the flora and fauna living on the sea bed. (3.8.3)
- bentonite - a naturally occurring form of clay. It has gel forming properties and is a principal ingredient in most drilling muds. (3.8.1)
- blind rams - rams on the blow-out preventer, used when the drill string has been removed to close the well. (3.9.3. See also Fig 2)
- blow-out - an uncontrolled surge of oil, gas or both from the well. (3.9.3)

blow-out preventer

- mechanism for stemming the flow of oil in an emergency to prevent a blow-out. (3.9.3. See also Fig 2)

B.O.P.

- blow-out preventer.

bridging

- collapse of part of the wall of the well during a blow-out, which effectively plugs the well and stems the flow. (3.9.3)

casing

- metal lining placed in the well. (3.7.1 & 4.6.1)

cap rock

- impervious layer of rock above a subterranean reservoir of oil which helps to trap the fluids in place.

Christmas tree

- system of pipes and valves at the head of a producing well, by which the flow of the well product is controlled and distributed. (4.6.2 and Fig 6)

condensate

- hydrocarbon in gaseous form in the formation, but which liquifies on being raised due to lower temperature.

connate water - formation water. (See below)

coring

- taking a rock sample from the well, not merely a drill cutting.

crude

- the crude oil derived from the well, after separation from gas and water, but before any other treatment.

diesel based drilling mud

- drilling mud in which the particulates are suspended in diesel oil and water. (3.8.2.)

displacement water

- water displaced from a storage tank as oil is added. (4.9.2)

drill collar - heavy steel pipe attached to the lower end of the drill string, and to which the drill bit is attached.

drill ship - a ship used for drilling wells. The drill string leaves the ship through the bottom of the hull. (3.2.4. See also Fig 1)

drill string - a series of pipes screwed end to end, to form a continuous pipe from a drilling deck to the drill collar and bit. (3.7.1 and Fig 5)

drill cuttings

- pieces of rock or other material cut out by the bit in the course of its drilling action. (3.7.2)

drilling fluid

- a suspension of particulates in a water or oil medium. It circulates down the drill string and up the annulus during drilling. (3.7.2 and 3.8)

drilling mud - a colloquial name for drilling fluid.

E.L.S.B.M. - See "exposed location single buoy mooring."

exposed location single buoy mooring

- a very large buoy at which an oil tanker can moor in order to load with oil piped from the production platform. (5.3.3 and Fig 9)

flare - a lighted flare, kept burning above the production platform, at which waste gases can safely be burned off. (4.1. and 4.6.2 and 4.11.1)

flush production

- See "primary recovery" below.

formation pressure

- pressure within the geological formation where the oil and gas lie. (3.9.1)

formation water

- water which was trapped in the subterranean formation with the oil. (4.9.1)

fracturing

- injecting fluid at very high pressure to break down the texture of the formation so as to increase production therefrom.

geophone

- instrument to record the vibrations which have been passed through the strata during a seismic survey. (2.1.4)

geopressure

- abnormally high pressure in the geological formation. (3.9.1)

gravimetric survey

- a survey which measures variations in the earth's gravity. (2.1.3)

hydril

- annular valve on the B.O.P. stack. (3.9.3 and (Fig 2)

hydrophone

- serves the same purpose as a geophone, but picks up the vibrations from the water. (2.1.4)

impressed current system

- a direct current passed through an underwater metal pipeline. When used in conjunction with an anode of inert material, it can lower the electrical potential of the pipe, and thus inhibit corrosion. (5.1.3)

injection water

- water injected into the formation from an additional well to increase the pressure there and drive oil up the producing wells. (4.6.1)

internal B.O.P.

- mechanism for preventing drilling mud from being forced up the drill string whilst a new length of pipe is added.

jacket

- main structure of a production platform to which the decks and equipment are added. (4.2.2)

jack-up drilling rig

- drilling rig with legs which can be raised or lowered. The legs can be lowered so that it stands on the sea bed with its deck well clear of the water. (3.2.2. See also Fig 1)

kelly

- a square or hexagonal length of pipe about 40 ft long screwed to the uppermost section of the drill string. It passes through the rotary table so as to carry the drive to the drill string. It moves down as the drill goes deeper, and is periodically unscrewed and raised for the insertion of a new length of drill pipe.

kelly cock

- an internal valve which can close off the drill string.

kick-back

- sudden upsurge of pressure from the formation. (3.9.1)

killing a well

- stopping the flow from a well, either after a blow-out, or during normal operations to start a workover or carry out other necessary work. (4.11.2)

LC/50

- a concentration of pollutant sufficient to kill 50% of fish immersed in it. It serves as a measure of toxicity, e.g. LC/50 at 2 ppm is highly toxic. (4.10.1)

logging

- drawing instruments on a cable through a well to record the surrounding formations and their properties.

low toxicity drilling mud

- a drilling mud based on mineral oil of significantly lower toxicity than diesel oil. (3.8.2)

magnetometer survey

- a survey which measures the variations in the earth's magnetic field. (2.1.2)

moonpool

- a hole in the hull of a drilling ship through which drilling is done. (3.2.4)

mud turbines - used in turbo drilling. (See below)

oil based drilling mud

- a drilling mud in which the particulates are suspended in a medium which may be water and diesel oil or mineral oil. (See 3.8.2 and "diesel based drilling mud" and "low toxicity drilling mud" above)

open hole

- uncased portion of a well. (See "casing" above)

packer

- plug which seals the annulus between the production tubing and the well casing during the production process. (4.7.2. See also Fig 5)

primary recovery

- production of oil raised by natural pressures only. Also called "flush production."

production water

- water which emerges from the well with the oil. Some may be formation water, some injection water. (4.9.1)

produced water

- production water. (See above)

production tubing

- tubing inserted down the well to carry the oil to the surface during production. (4.6.1. See also Fig 5)

relief well - a well drilled as part of an attempt to stem the flow of oil in a blow-out. It is drilled to open into the lower part of the blowing well, or into the nearby part of the formation. (3.9.3)

rotary table - the table on the drill floor which is power driven to turn the drill string and hence the bit. (3.7.1. See also Fig 5)

round trip - raising the drill string, e.g. to change the bit, and re-inserting it.

sacrificial anode

- A steel structure immersed in sea water will corrode. If it is connected with a mass of other metal of lower electrical potential, that other metal will corrode instead of the steel. Large pieces of zinc, aluminium or magnesium are attached to steel installations for that purpose. (4.2.2 and 4.10.2)

S.B.M. - single buoy mooring.

sea bed completion

- well head apparatus on the sea bed, from which oil is piped elsewhere for processing. (4.2.4. See also Figs 3 & 4)

secondary recovery

- raising oil by injecting water or gas into the formation.

semi-submersible drilling rig

- drilling rig kept afloat by buoyancy chambers, and usually kept in position by cables attached to the sea bed, (3.2.3. See also Fig 1)

shale shakers - sieves used to separate drill cuttings from drilling mud, which may then be recirculated. (3.7.3)

shear rams - rams on a blow-out preventer which can crush the drill pipe to seal off the well completely. (3.9.3 and Fig 2)

seismic survey
- survey of geological formations by sending into them a shock wave, which may be deflected and recorded on a special instrument. (2.1.4)

single buoy mooring
- large buoy at which a tanker can safely moor to load oil piped from a production platform. (5.3.2)

spar buoy - large buoy in the form of a vertical cylinder. used for mooring tankers for loading. (See ELSBM's) and which may contain chambers for storing oil. (5.3.3. See also Fig 9)

spud-in or spudding
- drilling a foot or so into the sea bed in preparation for drilling a new well.

step-out well - an appraisal well. (2.2.2 and see above)

stand-by vessel
- vessel stationed near to a rig or manned platform, in case of emergency. (3.3. and 4.3)

submersible drilling rig
- drilling rig which sits on the sea bed. Used in shallow waters. Now virtually obsolete. (3.2.5)

sub-sea completion
- see "sea bed completion."

suspended well-head

- head of a well which has been drilled and temporarily plugged for use later. (2.2.3 and 4.8.3)

thixotropic

- property of forming a gel when still, but becoming fluid again when disturbed. (3.7.2)

tubing

- production tubing. (See above)

turbo-drills

- drills which use the pressure of the drilling mud to drive the bit.

water based drilling mud

- drilling mud in which the particulates are suspended in a medium of water. (3.8.2)

water-flooding

- injecting water into a formation to force oil towards and up the producing well. It is injected through a separate injection well.

well

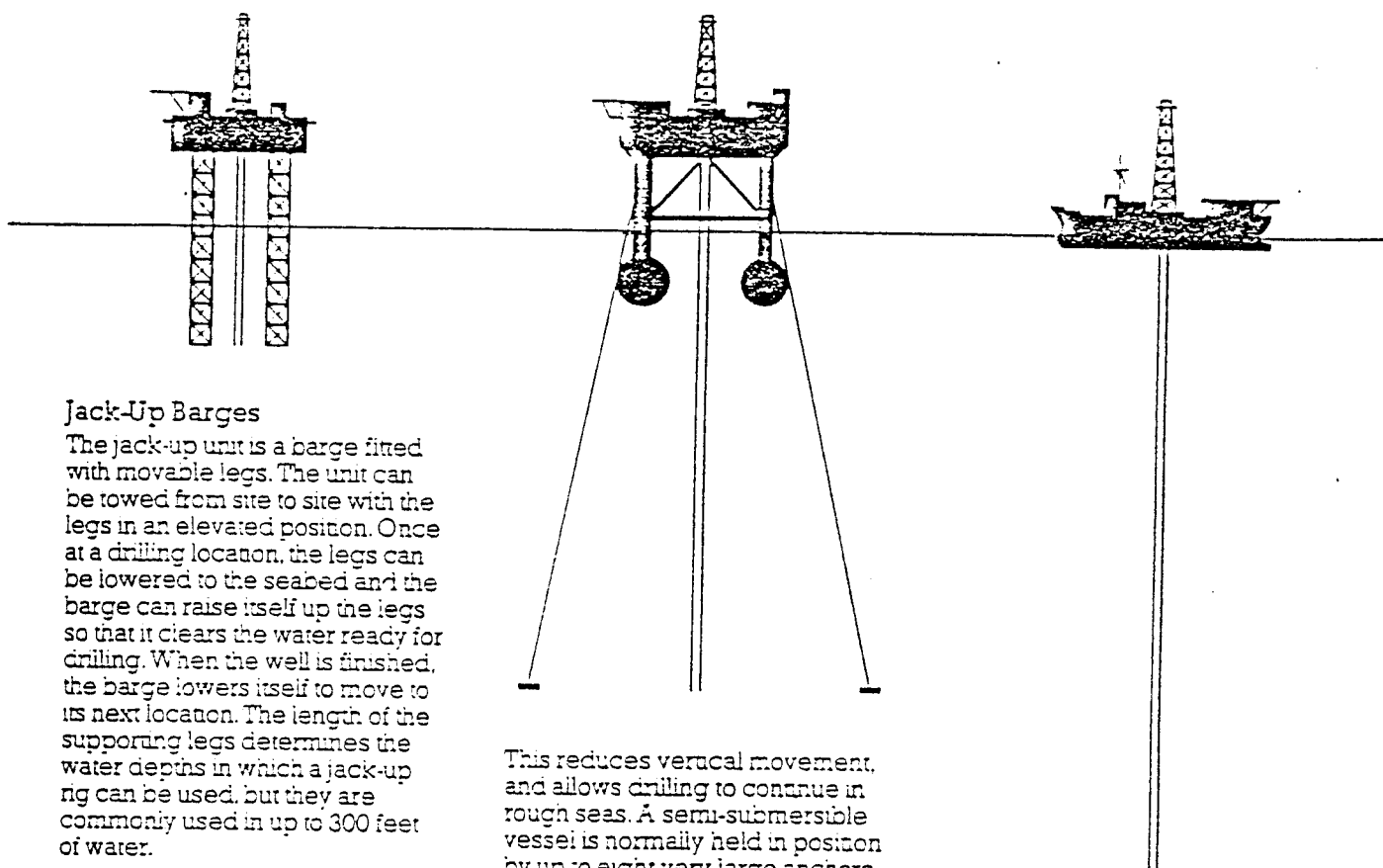
- each single hole drilled into the sea bed. (4.11.2)

workover

- major work of repair, maintenance or modification, carried out at the well-head or down the well. (4.11.2)

Fig. 1.

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Jack-Up Barges

The jack-up unit is a barge fitted with movable legs. The unit can be towed from site to site with the legs in an elevated position. Once at a drilling location, the legs can be lowered to the seabed and the barge can raise itself up the legs so that it clears the water ready for drilling. When the well is finished, the barge lowers itself to move to its next location. The length of the supporting legs determines the water depths in which a jack-up rig can be used, but they are commonly used in up to 300 feet of water.

To enable offshore drilling to be carried out in the deeper waters of the Gulf of Mexico and other offshore areas around the world, drillships and semi-submersible drilling units were developed.

Semi-Submersible Rigs

The semi-submersible unit is a self-propelled working platform supported by vertical columns on submerged pontoons, which provide buoyancy. By varying the quantity of ballast water in the pontoons, the unit can be raised or lowered in the water. The lower the pontoons lie beneath the surface of the water, the less they are influenced by wave action.

This reduces vertical movement, and allows drilling to continue in rough seas. A semi-submersible vessel is normally held in position by up to eight very large anchors, or by dynamic positioning. The design of the latest semi-submersible units enables them to drill in UK waters at depths of over 1,000 feet, all year round, despite the exceptionally high waves experienced in winter. The semi-submersible rig is the most widely used drilling unit in the North Sea.

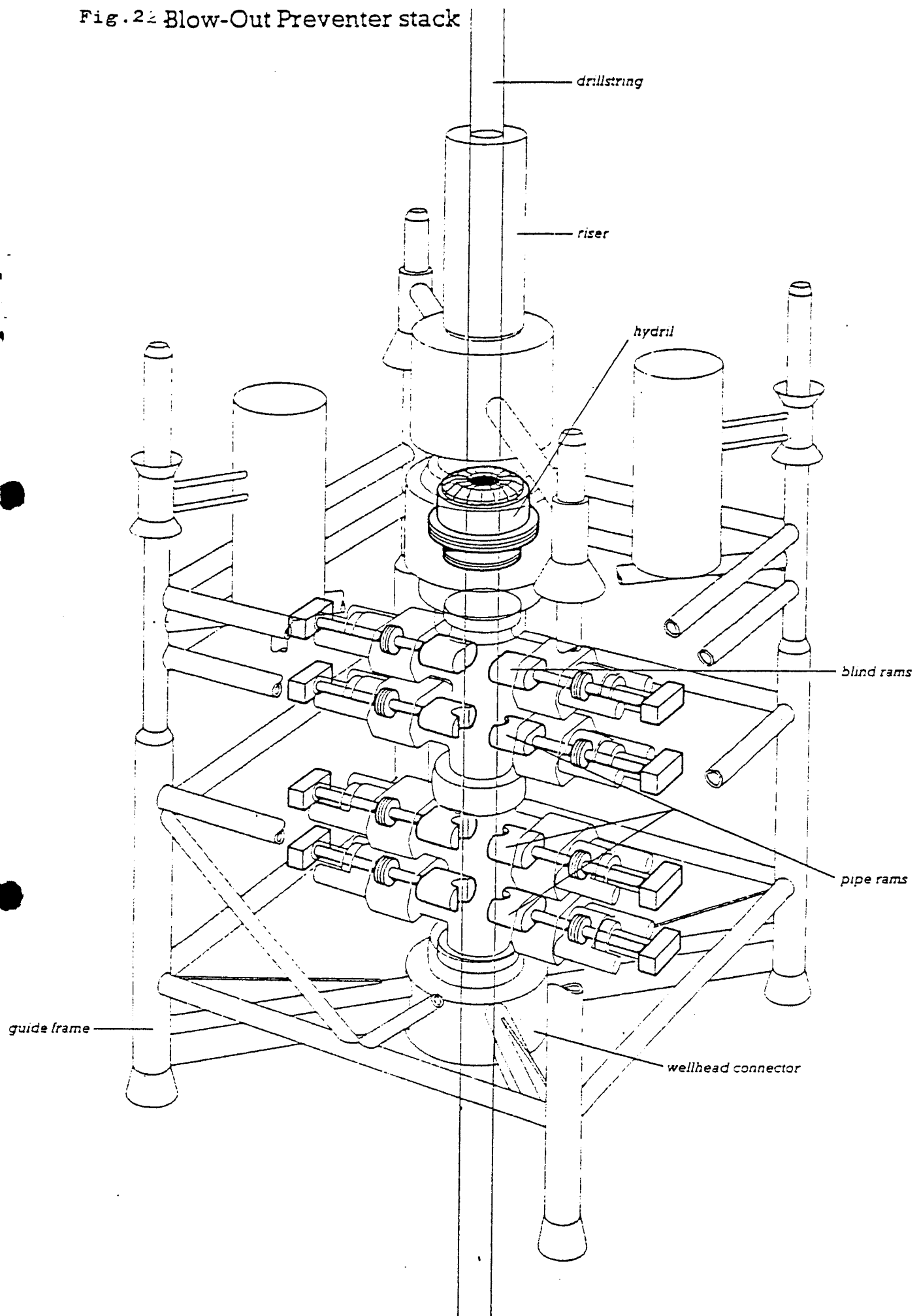
Drillships

A drillship is either a normal ship converted for drilling or a specially designed ship, allowing drilling to take place through an aperture in the centre of the vessel known as a moon-pool. A drillship can be moved easily from one location to another and

can store extensive stocks of drilling and general supplies. It is not, however, as stable as a semi-submersible unit.

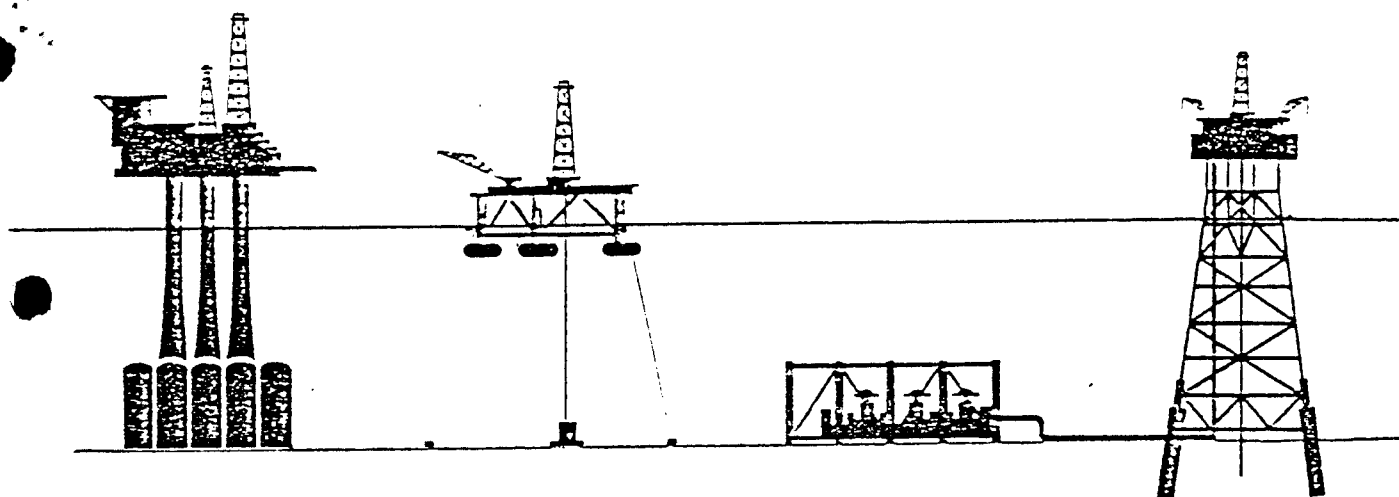
To overcome anchoring problems, which increase when moving into deeper waters, dynamic positioning has been introduced over the last decade, making anchoring unnecessary. Dynamic positioning systems use directional propeller thrusters which are computer controlled to keep the vessel stationary relative to the seabed, regardless of the action of wind, wave or current. There are now drillships that can operate in water depths of up to 5,000 feet.

Fig. 22 Blow-Out Preventer stack



(Note - no shear rams are shown in this diagram.)

Fig. 3.



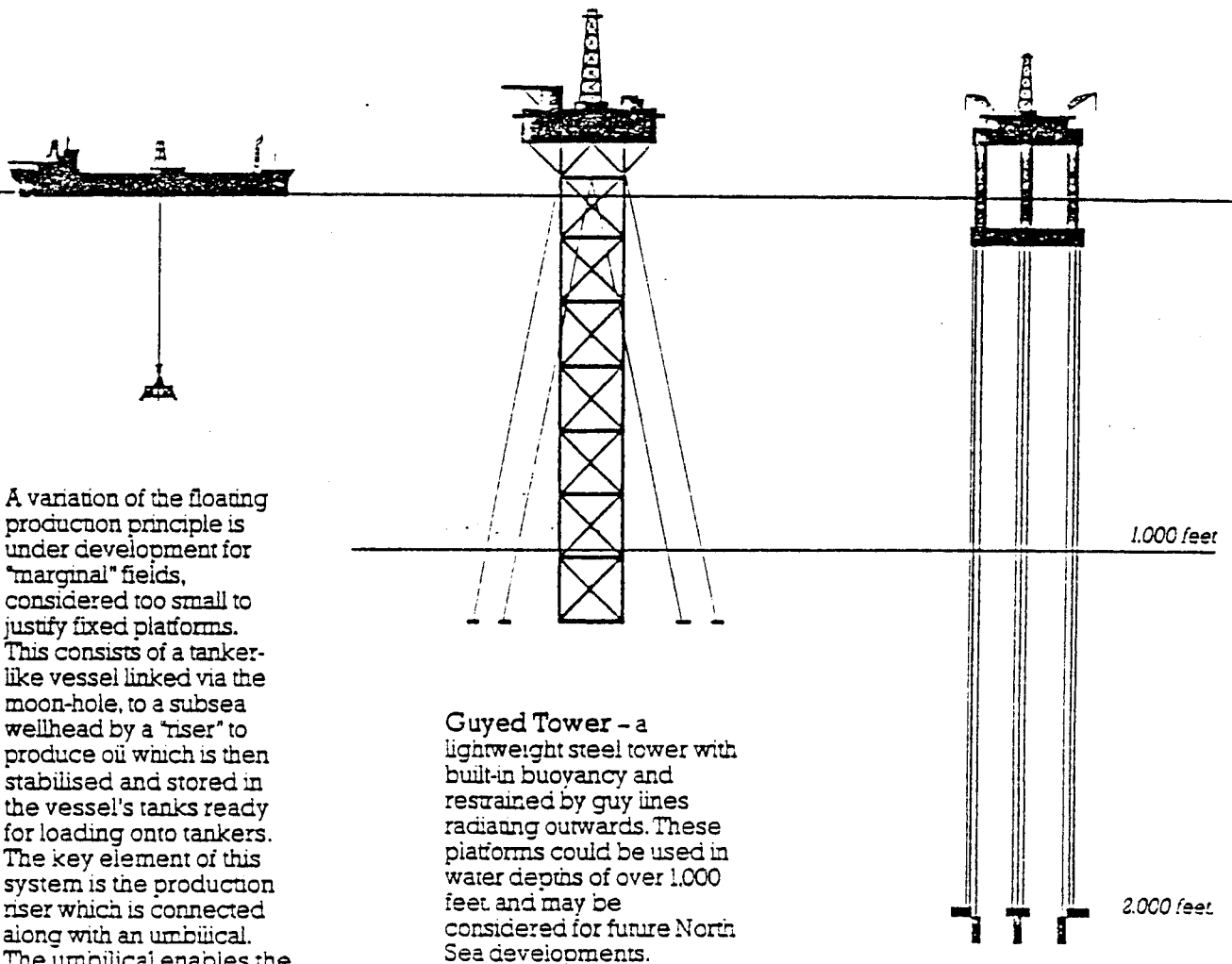
Concrete Gravity

Floating Production Systems: The sea-floor wellheads are connected, by production risers and hydraulic control hoses, to a specially adapted semi-submersible vessel on the surface. The oil is loaded onto tankers by means of Single Point Mooring buoys which can operate safely in moderate weather conditions. This system is already employed in the Argyll and Buchan fields, the former being the first UK offshore producing field in 1975.

Underwater Manifold Centre (UMC) is already installed in the Cormorant field and has been operational since May 1983. This system has all the wellheads on the seabed, and production is linked to a conventional platform by pipeline. The UMC is controlled from the platform and maintained by a submersible robot called a Remote Maintenance Vehicle (RMV). Subsea production facilities like the UMC will play an increasing role in the North Sea as companies look for commercially viable methods of developing small fields.

Steel Piled

Fig. 4.



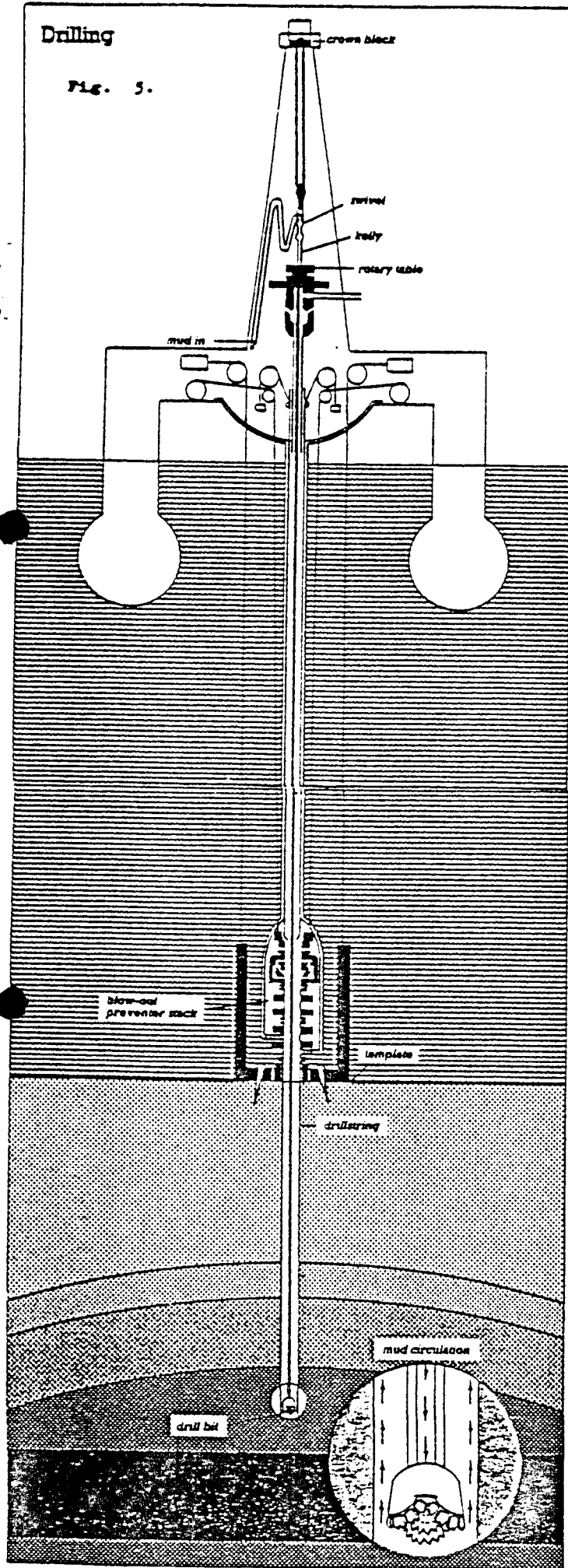
A variation of the floating production principle is under development for "marginal" fields, considered too small to justify fixed platforms. This consists of a tanker-like vessel linked via the moon-hole, to a subsea wellhead by a "riser" to produce oil which is then stabilised and stored in the vessel's tanks ready for loading onto tankers. The key element of this system is the production riser which is connected along with an umbilical. The umbilical enables the operations management to maintain hydraulic control of the well and riser systems from the surface vessel even in unfavourable weather conditions. One of the major advantages of this system is the ease with which the purpose-built vessel can be moved to a new field.

Guyed Tower - a lightweight steel tower with built-in buoyancy and restrained by guy lines radiating outwards. These platforms could be used in water depths of over 1,000 feet and may be considered for future North Sea developments.

The Tension Leg Platform (TLP) was developed to produce in water depths of over 1,000 feet. This technique involves tethering a floating production facility to the seabed, against its own buoyancy, by means of a series of steel tubes. The first commercial application of this new concept was installed in the Huron field which came on stream in August 1984.

Drilling

Fig. 5.



Production

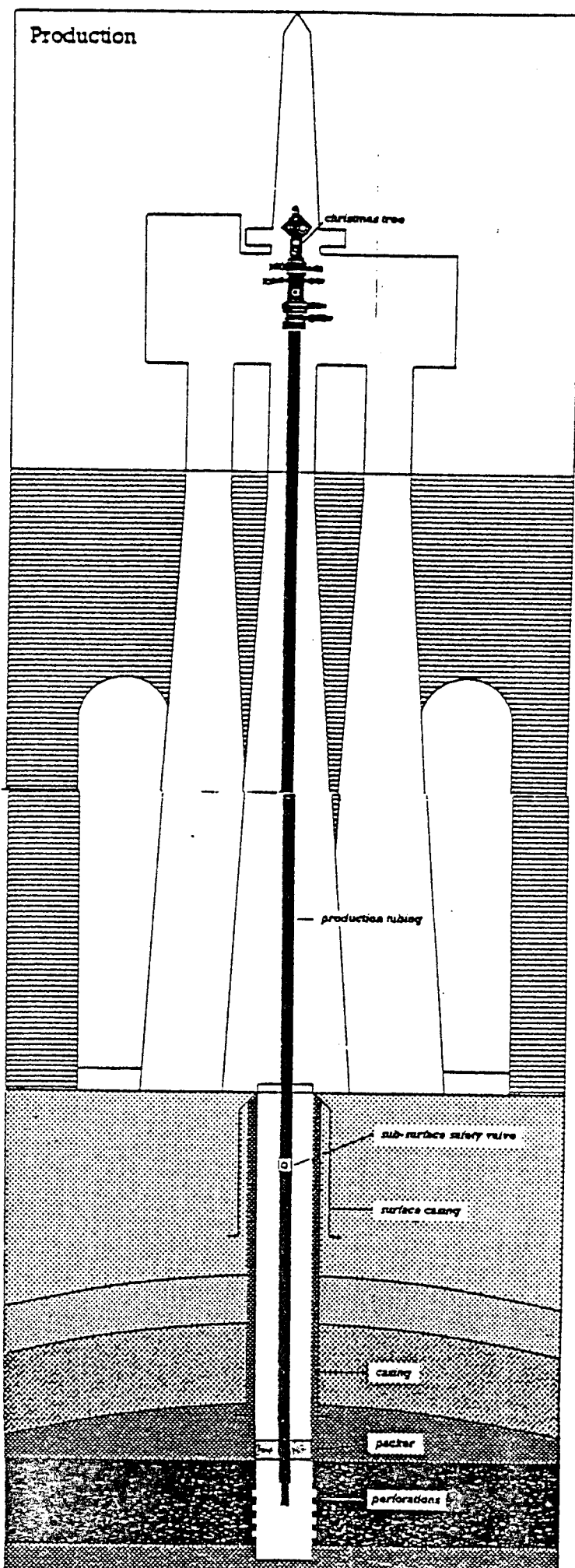


Fig.6.Christmas Tree

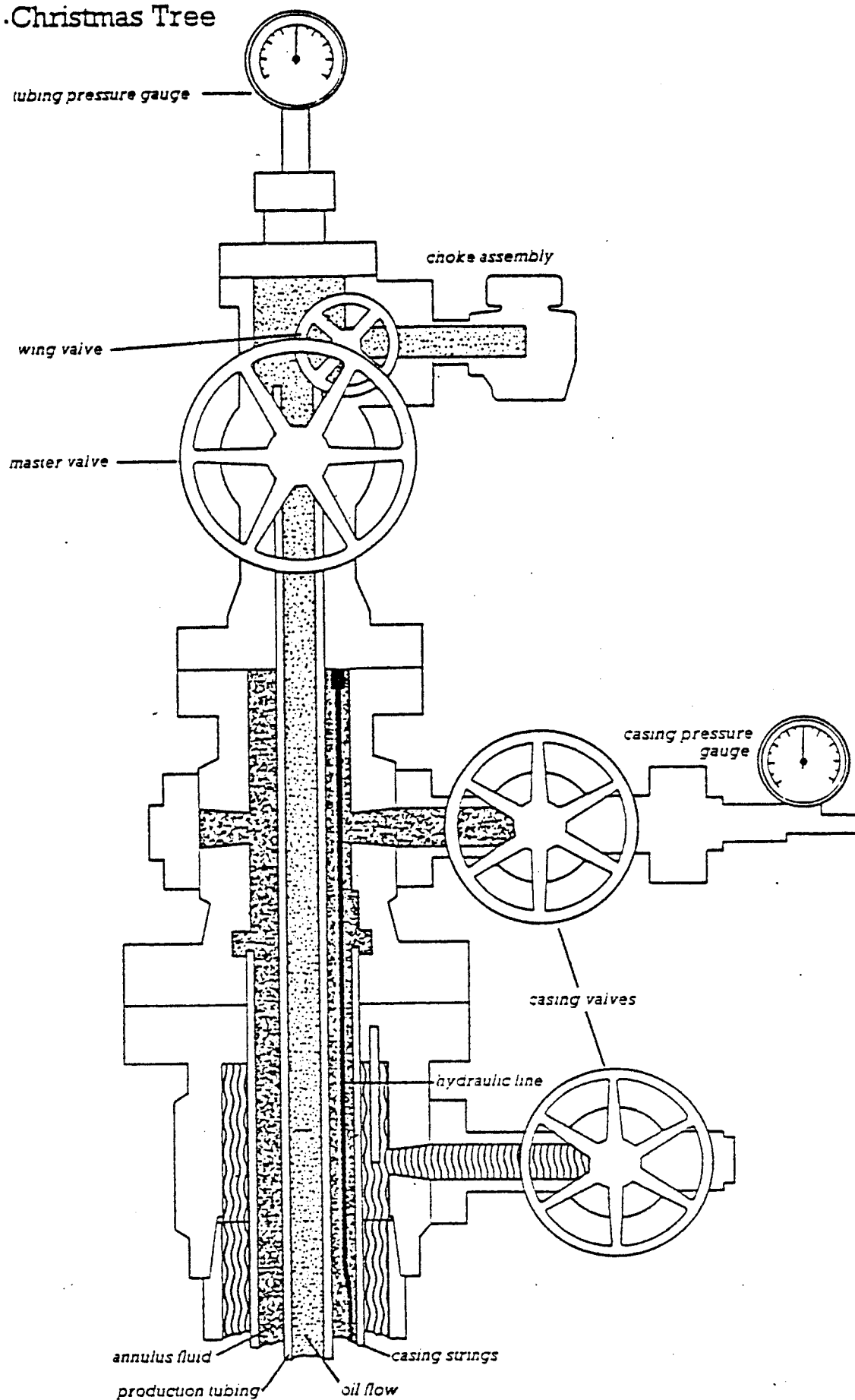
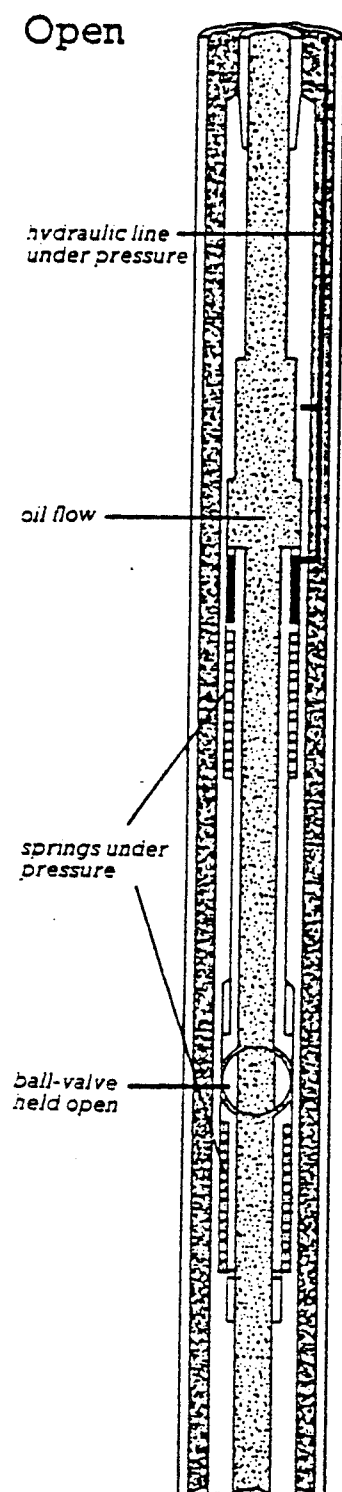


Fig. 7.

Sub-surface safety valve

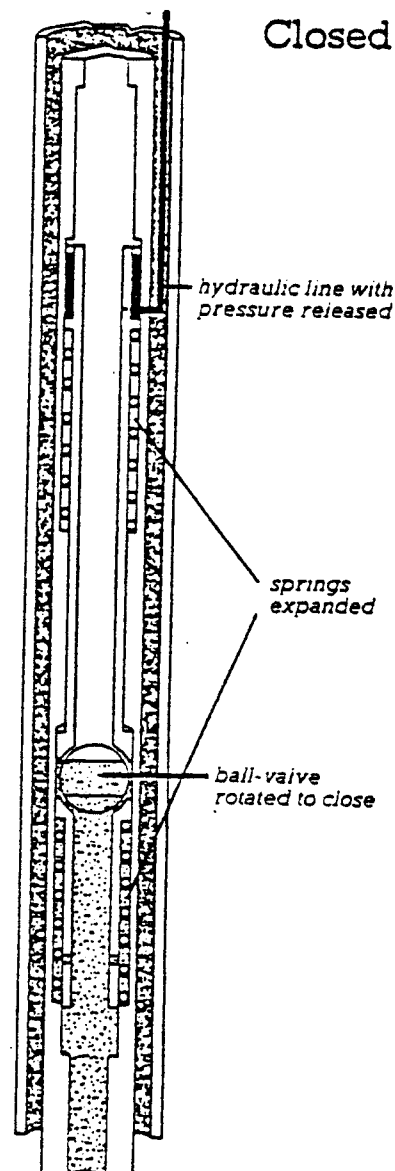


Two types of Down-hole safety valves can be used in production operations. The first, known as a storm choke, was developed for use in the Gulf of Mexico to prevent a blow-out occurring because of damage to the wellhead. It is placed deep in the well and is designed to close if the flow rate increases above a certain set level. This valve has in general been superseded by sub-surface safety valves, one of which is usually placed in the production tubing about 1000 feet below the seabed.

The operating principle of these valves is very simple. They are held open by hydraulic pressure supplied from the platform. Should this hydraulic pressure be lost due to rupture of the line or due to manual closure, the valve will automatically shut.

A typical design is shown here. In the open position oil and gas flows through the central hole in the sphere. On closing, the ball is rotated by the force of the compressed springs to shut off the flow.

The sub-surface safety valve is universally used in the North Sea. Its advantages over the earlier storm choke are that it can be regularly tested and that it works independently of the flow of oil or other variables. In some cases in the Gulf of Mexico, it had been found that the storm choke did not always close. This permitted an uncontrolled blow-out on one well, if it caught fire, to spread to other wells. Such spreading should be eliminated by the present use of sub-surface safety valves.



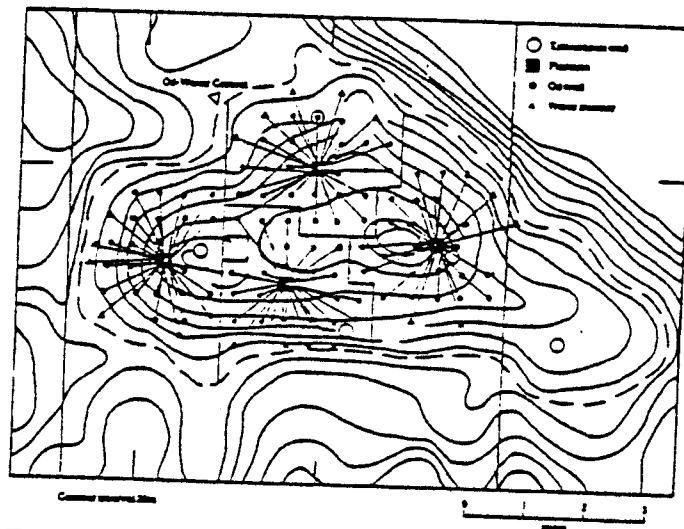


Fig. 8.

Example of Directional Drilling

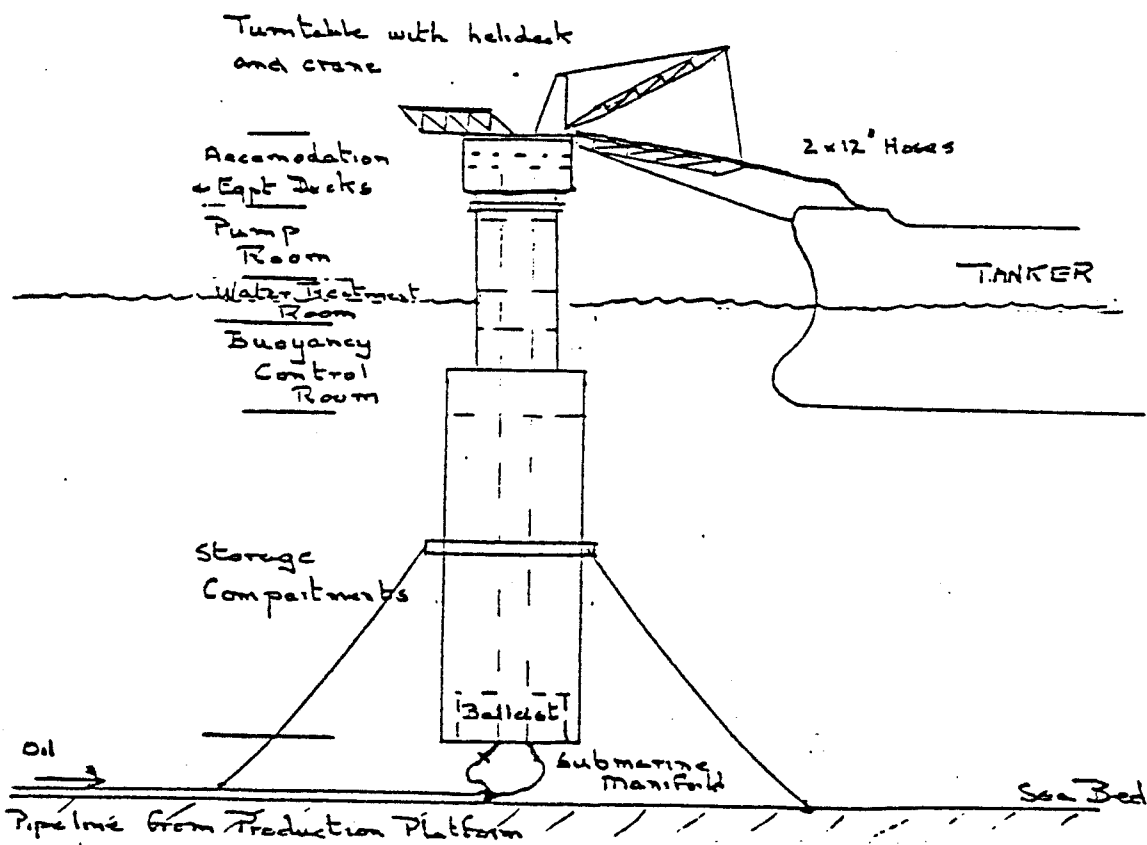


Fig.9. Loading Spar with Storage