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The Underwater Contractor: His Role and Development

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The underwater contractor: his rôle and development

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Recovery of hydrocarbons from the seabed has a long history, particularly in the Gulf of Mexico and Middle East.

Steps and processes required to extract oil from the seabed are essentially the same as those for recovery on land, but with the additional burden of bridging water depth.

The transition to exploitation of North Sea discoveries brought problems not always fully appreciated, the most persistent of which is still the unpredictable and harsh weather and sea conditions. The rate of exploitation and exploration depended upon the work speed in the more favourable surface conditions.

Experience and ingenuity have contributed greatly to reducing downtime. However, worldwide moves into greater depths and even less sheltered waters, stretch the suitability and cost-effectiveness of conventional structures and the techniques employed for seabed equipment maintenance and inspection.

Consequently, the recently developed concepts for installation and servicing of engineering complexes on the seabed are providing one of the most significant steps towards the goal of year-round operations.

1. The growth of the underwater contractor

In his opening remarks Dr Birks (1978, this volume) underlined the fact that the oil industry in the last five years has nearly doubled the depth of water in which it is exploring. It has much further to go yet.

Offshore hydrocarbon recovery over the last 25 years has introduced a new and highly specialized sphere of contracting. Compared with the way in which land-based operations developed, its growth and complexity have been both considerable and rapid. Pressures upon this development have increased also because of the political and economic price of oil in the North Sea at this point in British history.

The first steel structures offshore appeared in 7 m of water in the Gulf of Mexico in 1947, but by 1970 large structures in 150 m of water were becoming the norm. While offshore oil accounts for some 19 % of the total world's crude oil supplies with North Sea yielding approximately 4 %, the investment necessary must be regarded as enormous by any standards. By 1985 it is expected that offshore rigs will contribute 35 %. This gives some indication of the problems which must be faced and the investments which will be necessary. Work began in the North Sea in the Southern sector gas fields, followed by the oil fields Montrose, Forties, Brent and Ekofisk. The North Sea thus became well established as a development and production area. To meet these requirements a battery of specialized tools was necessary.

The almost overwhelmingly difficult environment, deep and exposed water, with high wind and wave conditions, were responsible for considerable delays and, indeed, will continue to tax the engineer's capability and ingenuity for years to come. Nowhere had such conditions previously been experienced, but the quality of the oil was considered to be excellent and its proximity to the market combined to offer great potential. In the future, oil production will move further north into still deeper and rougher conditions (including ice).

Oil-company financing of these vast undertakings requires the earliest possible returns from oil revenue and great pressure is brought to bear on contractors to obtain the earliest possible production and cash flow. In their turn these pressures provide the subsea contractor with commercial opportunities over this whole new field. The offshore and the underwater contractor in particular, are therefore presented with a challenging if daunting range of opportunities for investment and opportunities in the future. British industry really must take advantage of the North Sea to develop capabilities for later worldwide exploitation.

2. What the underwater contractor does

It will be appreciated that oil companies' primary interest is the end product and not the means of obtaining it. The cost of offshore hydrocarbon production is now so great that the resources of the oil companies are stretched to the limit to provide the necessary finance. Therefore, while the client oil company must identify his problems and his development direction, in his own interests it should encourage the contracting industry to develop and provide the means. Most contractors are hard-headed, down-to-earth 'doers' and forward thinking and development is not a way of life for them. Deep-water offshore work is much akin to space technology: virtually everything has to be undertaken in a hostile environment. Good science, good engineering and above all good safety and management of difficult operations are essential. The underwater contractor will rely heavily on vehicle and systems to be able to do his job safely and efficiently. The client oil company therefore frequently engages a project management contractor whose task is to manage the whole project on behalf of the client engaging, monitoring and managing specialized subcontractors to achieve the overall objective.

A total field management project would commence with feasibility studies covering all aspects of the development, including projected programmes, time scales, cost breakdowns, etc. Thereafter the contractor initiates, coordinates and oversees all design, manufacturing and installation services of the selected subcontract entities on behalf of the oil company.

The management of a programme from early subsystem development through to operation of a deep water field production demands a unique approach, balancing the risks incurred by new developments against the advantages of introducing them.

Some of these problems and their evaluation are of such magnitude that oil company/industry/Government/E.E.C. funding is essential.

The management of North Sea engineering requires a considerable degree of innovation which must be continually reassessed and fed back into an ongoing programme for future field equipment. It is equally important to ensure that, where subsystem development is taking place in discrete packages, each is pursuing the same long-term objective and this point is taken up later. The offshore and underwater engineering industries can learn much from aerospace and warship engineering traditions. However, the commercial end objective is usually seen in stark clarity and therefore in offshore operations empiricism and pragmatic solutions have an important rôle to play.

Management must constantly assess forecasts of resources, market requirement and development scenarios, the postulation of programmes to produce future engineering systems, and

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the identification of the key system elements or building bricks of the system; all this is aimed at making production under extreme conditions economically feasible and more cost-effective and commercially attractive.

Inevitably every application and oil field is different and a solution depends upon the precise specification for the particular field. In considering the strategy to be adopted therefore, the following criteria are dominant:

(*a*) Technical and financial risk to be minimized.

(*b*) The total package resulting from any innovation to be cost-effective to the industry.

(*c*) Government legislation and requirements to be met.

(*d*) Requirements of certification bodies to be satisfied.

Technological feasibility is a major challenge put increasingly to the test with the move into deeper waters. As a result, both technology and management are being stretched to their limits.

The oil company and its project management contractor have to work in the closest possible harmony and the latter is to be considered as an extension of the oil company's organization. There are, however, many specializations within the whole which call for expertise that can only be provided by organizations, individuals and teams offering tailored services. Both the oil company and the contractor, therefore, face immense investment risks but I would venture to remind oil companies that they will enjoy the profits of the end product – oil – in what can, in the longer term, only be seen as an expanding energy market.

A small sample of some of the areas in which the subsea contractor becomes involved is as follows:

(i) general area survey;

(ii) detailed block/area survey work, especially soil mechanics;

(iii) pipe route surveying;

(iv) provision of subsea facilities including wellhead, possibly encapsulation thereof, manifolds, riser, export line, flowline, satellite well, anchoring, pipeline trenching/de-trenching, subsea template, platform positioning;

(v) precise seabed positioning and measurement;

(vi) hook up;

(vii) scour/sand build up surveys;

(viii) manned wet/dry intervention system;

(ix) diver lockout maintenance;

(x) debris clearance;

(xi) inspection, maintenance and upkeep;

(xii) cathodic protection check;

(xiii) leak detection;

(xiv) photography;

(xv) equipment recovery at field close down.

The complexities, development and costs that flow from these activities are highlighted in one operating unit of my own Offshore Group. Analysis showed that to reach an objective in only four of the above subsea market areas, 96 development programmes would have to be initiated with costs ranging between £2000 and £2 000 000 (and this does not include the basic delivery vehicle).

3. A typical North Sea deep-water field development programme and its subsea elements

A typical North Sea deep-water production programme can take some 6 years to mature. However, as already mentioned, the oil company and the offshore subsea contractor seek ways of reducing this time, of cutting down costs and reducing the effects of weather. But the deep-sea underwater environment presents a number of difficulties: pressure, cold, visibility, navigation, provision of power, and surface weather; all of which increase costs and stretch technology.

The floating platform (in which mass will be a limiting factor) is one way in which cost-effectiveness is being improved. More and more equipment will be placed on the seabed to reduce weather downtime. The problem of the surface/seabed pipe connection or riser is currently receiving a good deal of attention.

Seabed drilling is terminated in a wellhead or 'Christmas tree' which is substantially similar to its land-based counterpart except for additional complications, such as temporary and permanent guide bases, remote operated control, flowline loops and connections. Wellhead equipment has to be wireguided from the surface and connected either remotely or using divers or submersibles, and then there is the problem of maintaining them.

The American Lockheed Company offer one solution with their subsea wellhead cellar, serviced from a diving bell or transit capsule from a platform or rig. A British solution for well-heads not necessarily under the platform is the submersible accessed subsea chamber from Vickers-Intertek. The system provides a one-atmosphere pressure chamber, but unlike the Lockheed cellar it remains a wet environment. Water is retained in order to simplify the structure required to reduce the risk of gas contamination, fire or explosion on the seabed, and to reduce power requirements. Access is gained via a proven technique of transferring men by transfer submersible to the seabed chamber The submersible lands on top of the transfer hatch of the chamber and secures itself without mechanical links by reducing the water pressure in the submersible's underwater transfer 'skirt'. Only a minimal amount of power is required to remove the small quantity of water needed to reduce the pressure in the seabed chamber from ambient to one atmosphere. The intervening hatch can then be opened without fear of the submersible's flooding, and maintenance operators who do not need to be trained divers can enter the system. The submersible provides power for lighting and a workshop facility for the divers to work in a one-atmosphere pressure environment.

A great advantage of both of the one-atmosphere systems is avoidance of risky, time-consuming and costly saturation diving methods necessitating long periods of diver decompression, although there is an ultimate depth restriction.

Offshore oil production involves the use of 'satellite' or 'step out' wells in addition to those underneath a platform. To avoid proliferation of platforms, it is necessary to connect these wells into a manifold and thence to the platform riser. Considerable pipework and cable inter-connection on the seabed is necessary, together with the means of laying, hauling in and making final connections. These are currently difficult problems and subsea encapsulations, habitats, chambers and the submersible have a part to play. Pipes and cables must be buried to protect them from damage by deep trawling and ships' anchors.

The subsea manifold centre acts as a collecting point from the satellite wells, for production testing, entering through-flowline (t.f.l.) tools, and export of oil to tanker loading buoys or ashore. The system is designed to be unattended in the main, with manned intervention only for installation and maintenance.

An Exxon subsea production system, currently operating as a test installation in the Gulf of Mexico, makes use of an electrohydraulic supervisory control system. Pumpdown t.f.l. tools are used for servicing, and a manipulator system, operated remotely from the surface, undertakes maintenance of the equipment which is installed in modular configuration.

A subsea completion under a floating platform would comprise the following (this concept is one of those engineered by my own company for a major oil company):

(i) a disposable drilling template;
(ii) encapsulated wellheads;
(iii) flowline connection from local and satellite wells into manifold chambers;
(iv) manifold chamber containing pipes, valves and controls in inert gas, having an accessible control chamber at one end and looking like a piece of nuclear submarine;
(v) connections to surface by riser/umbilicals.

At one point or another, all the oil and gas extracted from the seabed has to pass through a pipeline on its way to the shore. At any moment, from the time it is being laid onwards, a pipeline may need to be repaired. There is no alternative but to replace the damaged section, at present by mechanical means or by welding, with the use of divers. Both techniques have been used successfully in the North Sea. The contractor has to remove the surrounding seabed material to expose the pipe. The protective coating has then to be removed, the damaged section of pipe cut away and the pipe ends treated in readiness for re-jointing. The new section of pipe then has to be transported to the site and manoeuvred and held precisely in position, while the repair is effected.

As always, water depth plays an important part in the repairs. Conventional underwater wet-welding techniques become very unreliable as depth increases beyond 30–40 m due to the quenching action of the water. One solution has been to install a hyperbaric underwater welding habitat about the pipeline. A mechanical repair technique under development is that of Hydro-Tech in which hydraulically operated ball joints are inserted over the pipe ends.

Explosive welding is another method being developed. To date, consistently successful underwater welds are being achieved with 8-in and 32-in diameter pipes at depths to 120 m. The aim of this system is to dispense with divers entirely and to operate the system remotely from an attendant submersible. Welding actually occurs when an explosive charge inserted within the pipe forces together the individual plates with very high velocity. Structural analysis shows the weld area to be subsequently stronger than the parent metal.

Each of the jointing applications described can be and is being used also for the underwater connection of tie-ins, etc.

The submersible has played a vital rôle in the offshore scene since the 1960s. Much effort has been devoted to the development of the military submarine and we have come a long way from Foulton's submarine 'Turtle' of 1770! The world's first practical underwater submersible system harnessed to offshore engineering was pioneered by Vickers Oceanics in 1969 and now forms the basis of many deepsea operations. The versatility and dexterity of man as a diver will be difficult to replace. Sophisticated high-pressure-resistant diving suits like Jim stretch the diver's capability further. By the same token, the scope of work now being undertaken on the seabed could never have been achieved without the submersible.

Acceptance of the submersible for underwater work was a very long and slow process, but it

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is now seen to be the practical solution to a number of deep and shallow water problems. Typical submersible applications include:

one-atmosphere personnel transfer underwater;
pipeline route and platform site surveys;
pipeline inspection, burying/deburying and repair;
diver lockout services;
platform structural surveys and non-destructive testing.

With the exception of divers 'locked out' of submersibles, no decompression of the crew is required because of the retention of one-atmosphere pressure within the crew compartments. Power for the motors and manipulators is provided by batteries, which at present is one of the limitations of untethered manned submersibles. Efforts to improve battery performance or a successful alternative power source are a constant theme of research and development.

In the present submersible the battery mass is typically about 1.5 t representing some 10–15% of displacement – this provides some 50 kW h of energy capacity. Underwater power for tasks in the order of 15–20 kW are already encountered implying capacities of 120 kW h for 6–7 h dives. Other power sources investigated include the H.T.P. turbine (but we already have enough problems!), the I.P.N. turbine (pressure degrades performance, it pollutes and it is noisy), the re-cycle diesel engine, the Stirling engine, and the Alsthom fuel cell; all of which require further development. The need is great enough to suggest that substantially higher power sources for the submersibles or submarines of the future can be expected.

The recent introduction of a high-strength, high-technology glass-fibre reinforced plastic hull by Vickers has brought about savings in mass and maintenance tasks and given the benefits of additional buoyancy and power reserves.

The application of submersibles for diver lockout work enables the diver to be taken directly to his work site and once outside the submersible his life support, power for tooling, light source and supervision from within the clear-thinking one-atmosphere environment, are all provided by the submersible. This system is less prone than diving chambers to adverse surface conditions.

A special closed-circuit heating system to combat cold recently enabled a diver to establish one of the longest dives in the North Sea. He worked outside a submersible for $3\frac{1}{2}$ h at a depth of 467 ft at the Piper 'A' platform, in a joint Vickers/Oceaneering International effort.

As an alternative to manned submersibles a number of companies are investigating the potential of unmanned submersibles. Advantages include the safety aspect of dispensing with the need for men underwater, extra power for longer periods due to power supply via umbilical cable and a better facility than manned submersibles for operating from ships of opportunity, as opposed to purpose-built ships.

Although unmanned submersibles have proved their ability to undertake underwater tasks, they only contribute to the total answer. They may prove most useful in the rôle of underwater inspection of large fixed structures. Typical problems include a high degree of drag on the umbilical cable and hence a reduction in performance capability, lack of definition by the television guidance system and, like the manned submersible, in the shallower end of the market where divers can operate, lack of manual dexterity.

Summary

This paper has outlined some of the main areas of challenge facing the contractor at this time, crudely divided into two parts:

(1) the total overall project engineering and management activity;

(2) provision of specialist services and products.

While the first rests very largely at the door of the oil company and his appointed contractor, the second presents a bewildering selection of opportunities and pitfalls for the subsea contractor. Each avenue he explores opens up tens of further alternatives, presenting development-decision trees of substantial, and sometimes frightening, complexity. The engineering, marine and construction industries are already part of the way along the road leading to technical advances akin to those made in man's conquest of space. The speed with which solutions must be found is, however, a matter of the commercial targets which must be attained rather than national prestige. Management in these industries will have to grasp offshore opportunities for the U.K. Client oil companies and the government will need to play their part too in encouraging developmental investment.

In the pursuit of development, millions of pounds can be poured into large specific projects, when often the solution lies in smaller but related steps within a larger overall plan – in other words the identification of 'building blocks' leading continuously onwards and upwards in technology. Vickers development of the submersible *system* clearly demonstrates the method. The *vehicle* existed but the systems to deploy it, control it, give it suitable tools and recover it, were missing. Offshore subsea engineering will be a constant repeat of this situation.

Multi-sponsored projects involving E.E.C./Government/oil companies/contractors/suppliers are an attractive answer to funding innovative development: they can also lead on to partnerships and joint agreements which provide the resources necessary to supply the complementary services which will be required by North Sea and later worldwide offshore hydrocarbon and mining production.

The subsea contractor has made a remarkable contribution to sea-floor development – and from here on the pace will quicken. He will need to bring all the sciences to bear if he is to play his part in moving into deeper water. Not the least of these sciences will be the management science. He also must have a practical, common sense and healthy respect for the sea.