Cost Reduction in Offshore Engineering

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1. Cost-cutting in the oil industry

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SYNOPSIS. The collapse in oil prices in 1986 has forced the offshore oil industry to become more cost-conscious. Where this has led to increased efficiency the industry has benefitted. However, where investment has been indiscriminately cut back there is a danger of lost opportunity and lost value.

OILFIELD ECONOMICS

1. In the course of its life an oilfield passes through a series of economic phases: exploration, appraisal, development, production, and abandonment. At each stage of the field's life costs are incurred, and only while the field is producing are these costs offset by income from sales of oil. The economic viability of a field consists in ensuring that the benefits of positive cash-flow while the field is producing justify the costs of the investment made. The value of the field can in principle be increased either by raising income (for instance, increasing production or obtaining a higher sales price), or by reducing costs (development costs or operating costs). Here we shall look at the impact of cost reductions. Typical funds flows during the life of an oilfield are shown in Fig. 1.

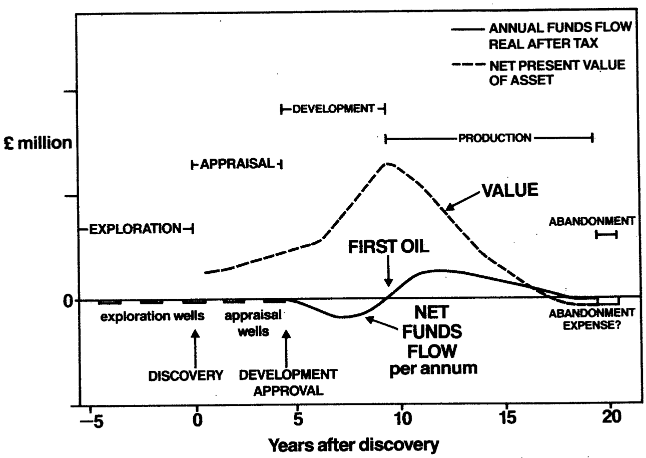

Fig. 1. Economic history of a hypothetical oilfield

2. During the exploration phase a series of investments are made on a risk basis. In the North Sea, typically between 5 and 10 exploration wells are required before a discovery is made, and each well may cost some £5-10 million. The wells are normally drilled on the basis that the expected (risked) economic benefit of the well exceeds the cost of the well.

3. Following discovery a series of appraisal wells may be required to confirm the discovery and satisfy the investor that the field is commercial. During this stage economic models are used to determine whether the prospect of long-term future revenue sufficiently outweighs the prospect of capital expenditure on development. This modelling process requires estimates of the following principal parameters: reserves volumes, development costs, development timing, production rates, operating costs, and future capital costs. Finally, it requires a view on future oil prices and exchange rates, and a view on the fiscal (taxation) regime which is likely to apply. The assessment is normally done on the basis of discounted cash-flow techniques (to determine whether the project yields a positive Net Present Value when all future after-tax cash-flows are discounted at a rate corresponding to the investor's cost of capital) or on the basis of Rate of Return calculations (which indicate the effective percentage rate at which capital is being invested). Most decisions are based on a combination of these two measures.

4. If the field is declared commercial and a development decision is made then several years of massive capital outlays may follow. Typical capital costs of development in the UKCS offshore are in the range £100-1,000 million, phased over 2-4 years.

5. Only when first oil is produced do positive cash flows begin, and even then the gross revenue from oil sales must of course exceed operating costs and recurring capital investment costs. At the point of first oil production the Net Present Value (NPV) of the field is generally at its maximum (Fig. 1): major negative cash-flows (the investment) are in the past, and the field looks forward to a long series of positive cash flows. Production from the field will generally proceed until cash flows turn negative - that is, until operating and necessary capital costs exceed the revenue from oil sales.

6. When production has ceased, the field has reached the end of its economic life, and the costs of decommissioning or "abandonment" must be faced. This is a stage which has not yet been reached in the North Sea, and it is not yet clear what the abandonment requirements will be nor what precise tax offsets will apply on the day. It remains an area of uncertainty.

OIL PRICES

7. Oil prices plummetted in early 1986. During the early 1980s prices remained apparently quite stable at around \$30/bbl, showing a slow decline to \$26-\$28/bbl by the end of 1985 (ref. 1, Official price for Saudi Arabian Light). However between December 1985 and July 1986 the spot price for Brent

crude fell from $26.50/bbl to $9.60/bbl. In real terms, allowing for effects of inflation, the fall in oil prices over the period 1980-1986 appears even more dramatic (Fig. 2) - in 1981 the price of oil in real 1987 dollars was $40/bbl, and had fallen by a factor of 4 by mid-1986.

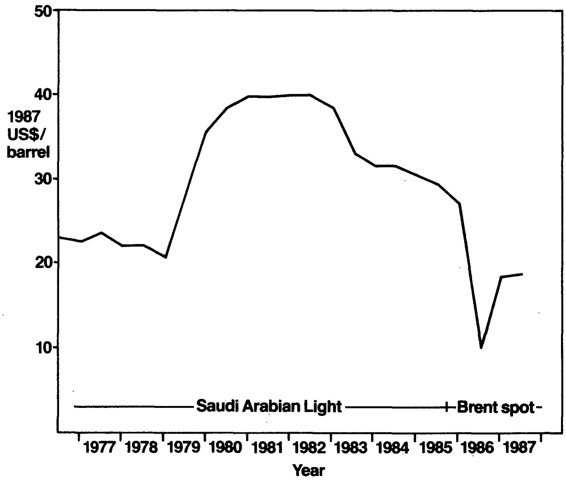

Fig. 2. Oil prices over the period 1977-1987, expressed in real 1987 US$/bbl. Official prices for Saudi Arabian Light are shown between 1977 and mid-1985 (ref. 1) followed by Brent crude spot price from end-1985 onwards. Historical prices have been converted to 1987 real terms by applying the US Consumer Price Index

8. The impact on the industry has been quite severe. As Fig. 3 shows, worldwide upstream net income of the Oil Majors generally fell by 50% or more between 1985 and 1986. For companies involved in continuing exploration and major investment programmes this led to cash flow problems, and cost reduction measures were rapidly implemented.

COST REDUCTIONS

9. At each of the principal stages of a field's life - exploration, development and production - it is possible to make cost reductions, but it is vitally important to emphasise that costs are only one element in a complex economic balance. Investment in the oil business is a long-term commitment, and a shrewd balance must be struck between the requirement for profit in the short-term and the desire for long-term value growth. This is exactly the dilemma faced by the investor in the stock market: should he concentrate on high long-term capital appreciation or on high annual dividends? In practice, a compromise must be reached, and the urge to cut costs must not be allowed to run riot: value depends not only on present costs, but also on future revenue. An operator may easily cut the number of exploration wells he drills, but in doing so may fail to find, fail to develop and fail to provide future

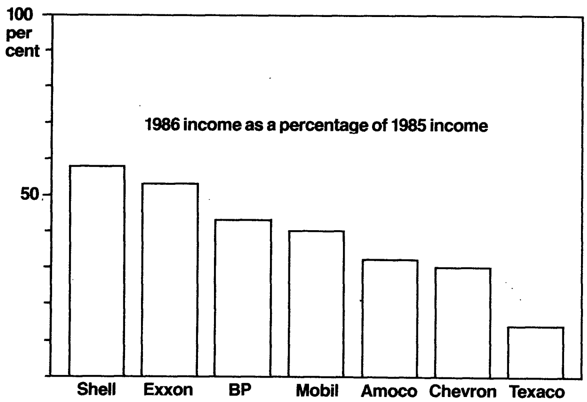

Fig. 3. Upstream net income of the Oil Majors: 1986 income expressed as a percentage of 1985 income. (Income is reported net income after corporate taxes and liabilities, adjusted for all exceptional and unusual items of a non-trading nature. Where necessary £ Sterling are converted to US$ at quarter-end rates.)

revenue; if cuts on development capital expenditure are indiscriminately imposed, then a field's production rates may be below optimum, or ultimate recovery from the reservoir may be threatened; and if present operating expenditure is cut unwisely, the operator may be exposed to higher future maintenance costs. So, although there have been efforts to cut costs over the last two years in order to solve short-term cash-flow problems, it is important not to allow such economies to jeopardise prospects for long-term value growth. At every stage a considered balance must be struck between reduction in costs on the one hand and consequent loss of future revenue on the other.

10. From the point of view of the owner or operator (as opposed to contractor) there are two types of cost reduction:

(a) "active" cost-cutting measures, involving changing or trimming activities and scopes of work; for instance, deferring or cancelling drilling plans, improving operational efficiency, reducing maintenance requirements or selecting lower-cost development options;

(b) "passive" cost reductions, as contractors' service costs (rig-rates etc.) fall in response to reduced demand. Passive cost reductions occur principally in response to active cost-cutting measures, and form something of a natural buffer against collapse in oil prices - although prices and revenue fall, so do costs, and the impact on activities is thus cushioned.

EXPLORATION

11. Exploration activities are the first line of attack in any cost reduction exercise, since wells may in many cases be deferred or cancelled, resulting in immediate apparent savings. In the North Sea, the industry uses exploration as a kind of balancing item in investment planning, since the degree of activity can be readily turned up and down according to availability of funds (ref. 2). However, although the adjustment is relatively easy to make, the savings are not great for a company which is able to write off exploration costs against production taxes at the marginal rate of 84%.

12. There are three categories of exploration well to consider. Firstly, a certain number of wells may be part of licence commitments, and the drilling programme has to proceed in any case. Secondly, the oil price collapse materially altered most companies' perception of long-term oil price prospects, and a number of previously promising prospects ceased to look economically attractive; such sub-economic wells were cancelled wherever possible. Thirdly, a number of wells which still looked economically attractive, but which did not require immediate action to satisfy commitments, were deferred in order to ease the short-term cash-flow constraints. It is this last category of activity which forms the principal balancing area, but it is worth emphasising that deferring or cancelling such wells does not increase value: quite the opposite - if wells have economic justification, then any delay in drilling and realising the asset they represent is equivalent to deferral of benefit, and diminution of present value. During 1985, a total of 157 offshore exploration and appraisal wells were drilled on the UK Continental Shelf, and in 1986 this fell to 113, a reduction of 28%. The long-term picture of drilling activity over the period 1977-1987 is shown in Fig. 4. Note, however, that although activity fell in 1986, it fell only to the same level as in 1982 - when oil prices were at the highest levels ever.

13. The deferral and cancellation of exploration wells also raises important long-term strategic issues for future development activity; exploration wells are the foundation for the future, and a period of subdued exploration activity now may result in a dearth of new developments coming on stream in the mid-1990s.

14. In response to the drop in activity level, exploration costs have fallen substantially, and this has provided some protection against more drastic cut-backs in activity. Fig. 5 shows how day-rates for semi-submersibles and jack-up rigs have responded to fluctuations in oil prices. In real terms, allowing for inflation, day-rates are now less than 15% of the peak rates in 1981.

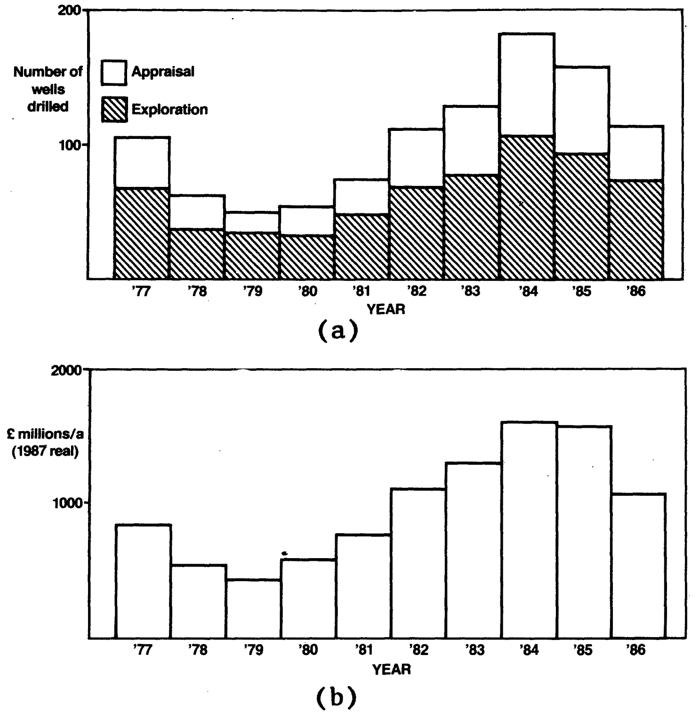

Fig. 4. Exploration activity 1977-1986 (ref. 3)
(a) number of exploration and appraisal wells started offshore on the UK Continental Shelf; (b) expenditure by operators and other production licencees on exploration activities (onshore and offshore)

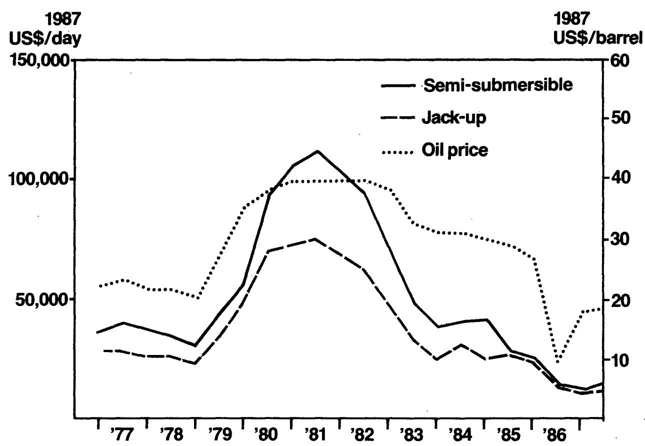

Fig. 5. North Sea day-rates for semi-submersibles and jack-up rigs over the period 1977-1986, expressed in real 1987 US$/day, compared with oil price (real 1987 US$/barrel)

15. Well services have shown significant reductions: logging services, although nominally unchanged in listed price since about 1982, are now being offered at discounts of some 40-50%. Casing costs have fallen by some 30-40% since 1982, but not necessarily in response to the oil price collapse (Fig. 6). Fracture stimulation jobs have fallen to less than half the cost they were before 1986.

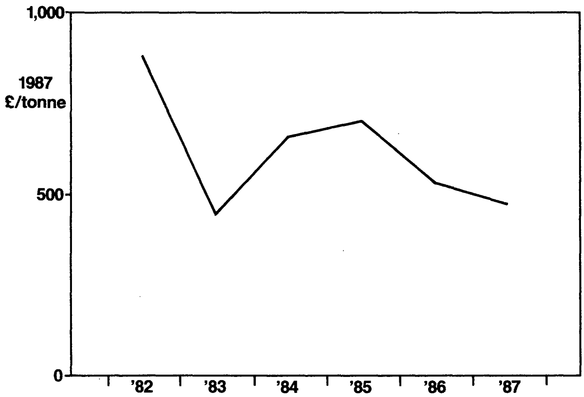

Fig. 6. Casing costs: average price in real 1987 Sterling per tonne, 1982-1987. (13 3/8" OD, 68lb/ft, Grade K55 Buttress, Range 3, seamless casing, UK delivery, North Sea use. Converted to real terms using UK CPI)

DEVELOPMENT

16. There has been little immediate visible impact on new developments, in the sense that no approved projects in the North Sea appear actually to have been cancelled. However, certain projects have been modified since commitment: for instance, at Shell's Eider development the original template and early well plan has been dropped in the light of new economics. The impact on future projects is perhaps more subtle: there has been an across-the-board re-assessment of potential developments. Some projects have become marginal under currently perceived conditions, and restricted availability of funds has meant that economically viable projects will not all automatically receive approval. This has led to "high-grading" of companies' project portfolios - only the most robust developments are now obtaining approval, and a number of projects have been delayed in the pre-project stage, undergoing reconsideration. The Miller field is a case in point: in May 1986, as the oil price fell towards $10/bbl, development was delayed by more than a year. As studies on alternative development options intensify we may see an increasing number of low-cost lean developments, making use of

very finely tuned engineering. For instance, BP's Q/8a gasfield, offshore the Netherlands, has been developed using a minimum facilities unmanned platform in 15 m water depth to recover a gas reserve of only 37 bcf; this is the smallest commercial offshore gas development in the world. Shell/Esso's Kittiwake oil field has also been developed using a "slimline" oil production platform - and capital costs have been reduced by some 40% from the original planned investment. Advanced technology is being applied in diverse ways in order to reduce capital costs: fracture stimulation of gas reservoirs in the Southern North Sea is being applied, to increase deliverability and reduce the number of wells and jackets necessary to achieve target production rates. A slimmed-down casing design (6-inch hole) is planned for completions on the Gyda development in Norway, with a corresponding reduction in well costs yet still with adequate deliverability.

17. Experience is also adding to efficiency. Project definition is continually improving as the technology becomes more familiar, resulting in tighter estimation of schedules and costs. Construction techniques are evolving and allowing substantial savings: most significant of all is the trend towards onshore fabrication and completion of increasingly large and complete topside modules. Offshore hook-up times and costs have been radically reduced over the last 5 years. At Magnus, in 1983, 2000-tonne modules were used, requiring some 200 man-hours/tonne offshore hook-up effort; at Ula, in 1986, 2000-tonne modules were used which required only 60 man-hours/tonne hook-up time; and currently the Gyda development, scheduled to come on stream in 1991, is planned with 5000-tonne modules requiring just 35 man-hours/tonne hook-up time. Contractors' costs have fallen, perhaps partly in response to decreasing demand, but also as a result of increasing efficiency and productivity. Jacket fabrication costs have fallen significantly over the last 5-6 years: costs in mid-1982 were typically some £3,500-4,000/tonne (1987 real terms), and by 1987/88 had fallen to between £2,500-3,500/tonne - in some cases as low as £2,500/tonne. A graph of topsides fabrication costs and jacket fabrication costs over the last 10 years is shown in Fig. 7.

PRODUCTION

18. The industry has made significant belt-tightening efforts in the areas of operating and further capital expenditure on existing producing offshore platforms. The principal areas in which major savings have been achieved are:

(a) drilling, workovers and well services
(b) maintenance
(c) logistics
(d) capital projects

19. Cost cutting has been achieved not only by specific major measures but also as a result of a general attitude of increased efficiency and cost-consciousness throughout

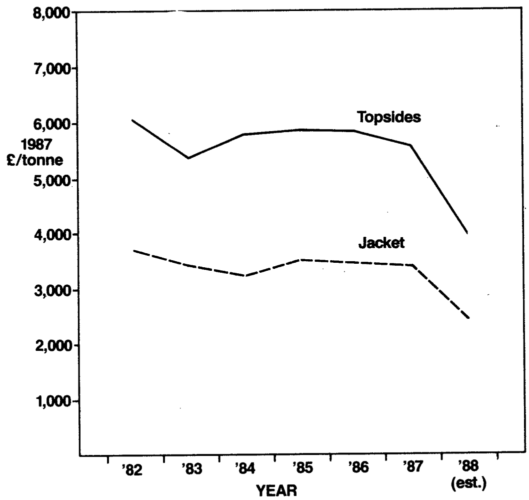

Fig. 7. North Sea topsides fabrication and jacket fabrication costs over the period 1982-87, (including estimated costs for 1988). Figures are based on an average of 16 North Sea projects

operations. Money has still been made available if justified on the grounds of safety, production or economics. The cost-cutting measures employed have not been allowed to affect safety standards, hydrocarbon recovery or achievement of production targets.

20. It is worth giving some specific examples from BP's two major offshore operations in the North Sea - Forties and Magnus.

Drilling, workovers and well services

21. Fewer workovers than normal have been carried out at Forties over the last two years: some were deferred, while others were made unnecessary by the use of bridge plugs to control water production rather than following the more traditional course of a full well workover. The artificial lift development test programme was moderated, leading to a lower replacement rate for electric submersible pumps (ESPs). The level of well-logging activity was reduced - and, as mentioned above for exploration activities, reduced logging contract rates were obtained as a result of the general downturn in demand. At Magnus, the development drilling programme was suspended from April 1986 to November 1987; this has served to defer costs rather than eliminate them, but it nonetheless constitutes an optimisation of value without corresponding loss of production. The novel deployment of a Diving Support Vessel (DSV) on a Magnus subsea well removed the requirement for a full workover, which would normally have necessitated the use of a conventional semi-submersible vessel, at considerably greater cost.

Maintenance

22. At both Forties and Magnus, maintenance intervals for equipment have been extended; this has been achieved by increased use of condition monitoring of major plant to determine whether maintenance is necessary, rather than keeping to fixed 3, 6 or 12 monthly inspection intervals as were used formerly. For example, up until 1986 the flares on the Forties platforms had been routinely renewed each year during the annual summer maintenance shutdown; however, in 1986 the flares were inspected and judged to be fit for a further year until changeout in 1987. This also meant that the annual field shutdown was replaced by shorter platform shutdowns. At Magnus there has been a major reduction in topsides painting, and a strict upper limit on spending has been imposed. There has also been a general policy of allowing a backlog of non-urgent maintenance to build up to higher levels rather than employing extra personnel to work on it.

Logistics

23. There have been general reductions in usage of supply and support vessels, as a result of more efficient utilisation and also the knock-on effect of reduced levels of workover activities; this, combined with lower market rates, has led to significant savings. At Magnus, supply vessel sailings have been reduced from 3 to 2 per fortnight, and subsea inspections have been reduced to the statutory minimum. At Forties the Iolair emergency support vessel is now used more extensively for subsea operations, and this has meant that no contract diving vessels needed to be employed at Forties during 1987. At Magnus the frequency of helicopter flights to the platform has been reduced from 11 per week to 9 per week, which occasionally results in personnel spending extra nights offshore until spare seats occur. In the Southern North Sea, pooling of helicopter and vessel fleets has led to cost savings, which will become even more significant as activity levels increase.

Capital projects

24. More stringent justifications are now being required for major capital projects. An economic criterion has been introduced at Magnus which requires any project not strictly required for safety or operational reasons to pay back the capital investment within one year. For example, a project to convert the injection water deoxygenation tower from gas-stripping to vacuum-stripping operations was rejected. The revenue generated by selling the gas previously used in the tower did not satisfy the one year payback criterion.

25. All these measures have led to significant reductions in the costs of our offshore operations. At Forties, cost-cutting measures have resulted in an overall reduction of operating costs by 21% in real terms over the period 1985-1987.

CONCLUSIONS

26. Cutting of unnecessary spending is, of course, a good thing. Over the last two years, cash flow constraints have forced operators to ensure that all expenditure on producing fields is strictly necessary, and as a result operations are now more cost-efficient. The value of the producing fields has been optimised without loss of hydrocarbon recovery and, as far as we can tell, without deterioration in safety standards.

27. The same may be said, to some extent, of the pre-project side of the industry: potential developments are being closely tailored to achieve maximum return for minimum cost, and this, too, is admirable so long as it does not affect recovery factors or safety standards. It is, however, a more serious matter if contraints on availability of investment capital mean that economically attractive projects are unable to proceed. We have yet to see whether the collapse in oil revenues will have this effect, but in the meantime reductions in capital and operating costs should help ease the passage of potential projects towards development approval.

28. Constraints on spending may have a serious effect on the exploration side of the business. If a prospect is worth drilling, it is worth drilling - and to defer or cancel a well is a lost investment opportunity, not a saving.

29. In all aspects of decision-making in the offshore oil industry we must pay close attention to full economic evaluation of the consequences of reduced spending. Optimisation and cost-efficiency are praiseworthy objectives, but relief of cash-flow problems through reduction in activities may very well jeopardise prospects for long term growth. Our aim must always be to add value, and bear in mind that costs are only one side of the equation. It is one thing to become leaner - but it is important to become fitter as well.

ACKNOWLEDGMENTS

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2. Competition in project development planning

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SYNOPSIS. Techniques utilising various forms of competition may be used to enhance low cost design during project development planning. A number of techniques are discussed including study competitions, study teams, competition against previous project performance and finally planning the competition for fabrication and installation.

BACKGROUND

1. North Sea oil and gas exploration is in its maturity. The flush of large new discoveries is probably over but there are many smaller developments. Generally these smaller developments are more difficult to make economic, a problem compounded by current oil prices; a situation which demands ways be found to reduce traditional cost and schedule durations if developments are to proceed.

2. In earlier North Sea days, with large fields, the best economic position was to achieve production as quickly as possible, obviously, with regard to the cost but with no necessity to work at cost cutting. It still is a sound economic objective to achieve as early a production as possible but now cost saving is something needing extra careful consideration.

3. Current smaller fields are not as economically robust generally as the large fields of the last decade. Ability to accept cost and schedule overruns and still attain economic viability is very limited. In this environment low risk, as well as low cost and a short schedule are a necessity to healthy economics. Cost reductions, shorter schedules and reduced risk can be achieved by the use of innovative technology, skilful project management, and improved efficiency. Care though, is needed to ensure any increased risk in the new technology is identified.

4. Very easily, the additional risks can be unacceptably larger. Experience with new technology suggests actual cost can be out by many times those estimated. On one Conoco project some years ago, utilising some of the first North Sea subsea trees, cost turned out seven times more than the original estimate. Novel mooring system components on a more recent project were 22 times the original cost estimate. It is important, therefore, to very carefully assess and manage risk.

5. Ideas and concepts in both technology and project management methods need to be investigated with the object of identifying lower costs and shorter schedules with acceptable risk. There is a limit, though, to what can be gained from a generalised study; a study directed specifically at a development always seems more productive. However, the further into a project we go the less design changes we want; design changes during detail design are recognised to be a major cause of cost overruns and project delays. To avoid these problems it is best to analyse and incorporate new ideas during the project planning phase, but how to create innovative ideas?

6. To identify potential new methods is not easy and some way to stimulate ideas is required. Some possible ways involve competition in some form, and this paper is about these methods.

COMPETITION IN THE DEVELOPMENT PLANNING CYCLE

7. Competition in various forms can assist in the development planning phase of a project. Usually, after having conducted a feasibility study the next step is to carry out conceptual engineering. What normally happens is we try to identify a number of field development options. It is usual to study four or five such options. A good way to help determine possible ideas and then ensure each is thoroughly investigated, is to use contractors in a "study competition." Design contractors are assigned an option to study in competition with other contractors developing alternatives. To ensure fairness the client has to maintain a close and continual detailed monitoring role.

8. After conceptual engineering, we normally finish up with two good concepts that we want to progress a little further before making a decision. This is where the next competition idea, that of "study teams", is useful. The method here is to set up independent teams to study each of the options. The teams can be formed of people from the same company or comprise personnel from a number of different organisations. Each team champions a concept, then in competition, tries to develop its case to show it is the best and to have it selected for the development.

9. While the final selection of a concept is taking place other groups will be planning the project management

strategy. It is suggested the objective should be for the new project to be in competition against the performance of prior projects, with the intention to have a far better performance than achieved previously. A starting point for this is an in-depth review of completed projects. Successful project management methods are identified for adoption whilst previous problems are noted for avoidance.

10. Shortly after the concept studies have been completed initial process engineering will be available at which time innovative equipment may be considered for inclusion. Unfortunately innovative equipment does not become available very frequently. Furthermore proving trials are going to be necessary before adoption is possible. What is suggested is that existing suppliers and new technology companies should be encouraged to compete vigorously by providing new innovative equipment. This does not mean big R & D budgets, but probably does mean offering test facilities or side-stream facilities to prove equipment.

11. A final aspect of competition is in an area where competition is well appreciated and understood and that is in fabrication and installation contract bidding. However, it is suggested for the most effective treatment, early planning of the contract strategy and design basis is desirable to ensure a number of contractors are able to provide their lowest priced bids. Studies during project development planning to identify fabrication and contract methods aid selection of the correct strategy. These ideas are explained further in the following paragraphs.

USE OF CONTRACTORS IN A "STUDY COMPETITION"

12. A very useful way to stimulate ideas in the planning phase of a project, is by using different contractors to study concepts in a "study competition." The method requires a number of development concepts to be identified for study. Contractors are then selected to bid on a basis of their specialist abilitiies. Each contractor is also requested to provide any of their own ideas for study. Cases and contractors are then selected and matched on a basis of one concept to be studied per contractor. Not unusually, four or five small contracts would be arranged. The operator has to secure regular reporting to ensure the best ideas are being explored as well as maintaining a close monitoring role of the progressing work. In fact, the operator has to provide an essential link between the contractors to ensure the competitive pressure is maintained, schedules and targets met, and fairness in the final comparison is achieved. All the contractors selected to conduct studies are chosen because of some specialist ability. That means the best expertise for each concept is being used and all the concepts are studied as thoroughly as possible. Needless detail is kept to a minimum as the smaller parcels of work placed with each contractor are more easily controlled.

13. Individual contractors know they are in competition during the study so if they are to keep their concept in contention they have to produce that bit extra. A further incentive is that the contractor who works on the winning concept has that much more chance of the follow-on work in the remaining parts of the project.

14. Such study competition was used recently to consider abandonment ideas in the Southern Basin. We had some 18 months before the more recent study commissioned a single contractor to look at abandonment. Unfortunately a little after this study was complete we realised that we were not satisfied with the cost estimate produced - we thought it high. It was decided, therefore, to commission another study. This time, though, rather than commission a single engineering contractor we used a "Study Competition" with a variety of different contractors to look at various minimum cost concepts. We used engineering design contractors, marine contractors and salvage agents. The answers we got were all correct in the way estimates were prepared for the given removal concepts but had a proportion of 1 to 2 between lowest and highest estimated cost for abandonment. We drew together the various ideas and composed a solution somewhere in the middle we felt comfortable with. The total expenditure to conduct all four studies was not dissimilar to the cost of the single initial study. By having done the four studies we obtained a lot better spread of ideas and determined a solution 40% of that proposed by the initial single study, a considerable cost reduction. (The differential is in addition to decreases in marine vessel rates during the period).

15. A further example of study competition was for a Southern Basin Minimum Facilities Platform. Four contractors were involved, each to look at a different structure ideas again in competition. The engineering cost of each study was kept quite low. Only essential work was done to prove a concept and cost it. At the end of the study we had four very workable structures, only one of which was anything like what we had used previously. All the ideas showed a considerable saving on what had been used before. From the study we were able to determine a preferred concept for a specific field development. For another field one of the other concepts could prove better; specific economics having to be developed appropriate to flowrates, number of wells, field life etc. Our feeling was that we could not have got the same result from a single engineering design contractor whilst we finished up with an excellent result at little cost for the study. In fact, we would have probably found it difficult to control a single contractor, who would have developed unnecessary detail and not have been able to provide such a broad spectrum of ideas.

COMPETITION BETWEEN STUDY TEAMS

16. The "Study Team" technique is particularly useful to develop two rival concepts. One of Conoco's earlier uses of the technique was to compare a steel jacket with a TLP during the project development planning of Hutton. In a more recent study comparing large modules against an integrated deck, one team championed modules whilst a second championed the integrated deck. The teams comprised people from a number of organisations. In fact, another operator led the work, we had people in both teams as did a contractor. What was found was that optimisation of both concepts took place, with considerable savings on previously forecast costs. A lot of pressure was put on the teams because of the competitiveness to prove their concept was the best. Each team was really out to win. The need to remedy disadvantages and find advantages really stimulated innovation. Innovative ideas by one team seeded ideas by the other team, who would see a way to use the first team's idea or build on it in some way.

17. The pressure would have been nowhere near the same if only one team was doing the comparison. With a single team there is a tendency to reach a conclusion quickly whereupon the individual team then starts to just prove up the preferred choice. Recently we did studies on Southern Basin developments in which we compared subsea wells against wellhead platforms. Only one team was used with a strong team leader, time and resources were short, and quickly it became apparent to the team that the subsea option was advantageous in the particular circumstances we were considering. The study was completed and a few months passed, people who had been in the original study moved on to other work. A new team was set up and asked to show that a wellhead platform could be more economic than the previous subsea study, - they did.

18. A nagging thought is - even now have we optimised as far as reasonably possible? It may have been more efficient to have had the two teams working at the same time, then they could have really challenged one another and achieved possibly even better results than we have so far. We would have felt then that we had pursued all avenues on both options as far as we possibly could.

19. Competition in such teams is just one way of putting people on a knife edge and really making people produce that bit extra that makes all the difference. Tom Marr, a spokesman in the Murchison Project Film, used similar words to describe site involvement in fabrication yards. Getting that bit extra out of people is what good management is all about. A requirement that is equally important at any time and not least in the front end planning when significant cost reductions, short schedules and reduce risk developments are formulated.

COMPETITION AGAINST PREVIOUS PROJECT PERFORMANCE

20. To achieve the best project performance a good way is to start with the intention to be in competition to do better than previous projects. The advantage of taking a close look at all the previous similar projects is well understood. In Conoco we saw significant advantage from such a survey on Murchison. It was seen as a competitive situation that Murchison would be better. At that time in the so-called first generation of North Sea developments, considerable overruns of time and money were common. Conoco charged a team to review all the information available from previous projects and obtain what information was possible from the people involved. Many people, operators, partners and contractors, were prepared to discuss their experience.

21. The resulting report was used on Murchison to determine the project management philosophy and plan. The lessons that came out of that report are just as relevant today.

- A Project Team comprising sufficient dedicated members and backed-up by task forces to solve unforeseen problems.
- Freeze design concepts as the front-end engineering is complete and progressively as more detail is developed. Set-up formal procedures and review boards for considering overall effects and values of design changes.
- Do not assume that cost, designs or contracts for previous projects can be simply scaled up or down or copied.
- Use "risk management" probabilistic scheduling techniques to help make critical schedule decisions.

The competitive element and information from the pre-project survey were seen as a significant contribution to the success of Murchison.

COMPETITION IN SUPPLY OF INNOVATIVE EQUIPMENT

22. During project development planning efforts to locate innovative equipment are an important part of cost reduction. Competition by vendors in developing new equipment is happening but not fast enough. Many opportunities exist for considerable cost reduction if the right equipment can be developed. Generally the process equipment used offshore is based on well understood but long standing technology. Although well tried and proven, the equipment extracts a considerable penalty in weight and space for offshore North Sea use. Potential savings are compounded when it is considered the weight and space saved in this primary load is saved many times over by the reduced requirement for support and ancillary equipment.

23. One way the competition could develop is by new companies entering the market. There is real opportunity for existing and new smaller companies to develop a technological lead for a specific item. Opportunities exist in many areas, particularly the oil separation, water clean-up, water preparation and drilling equipment. It is in these areas where currently large pieces of equipment are used.

24. The current developments with water clean-up hydrocyclones, which are replacing equipment many times heavier and labour intensive, show what can be done. Vortoil was a small company that took the hydrocyclone idea and developed it into a very successful product that has challenged the traditional water clean-up manufacturers.

25. Water clean-up and preparation comprises 25% of total topside weight so there are many more opportunities besides hydrocyclones in this one area alone.

26. In another area separation equipment is the simplest of equipment but weight and space intensive, another challenge for application of technology to cost reduction in the offshore environment.

27. In drilling, top drives and auto pipe-stackers are all relatively new developments, but running in and out of hole with the drill string is an obvious area for greater automation. Anything which reduces the number of people offshore has knock-on benefits in that less support facilities are needed offering a substantial cost reduction.

28. In summary, many opportunities exist for high technology companies to enter the offshore market with proven technical products and compete with the more established companies to the general benefit of the industry. One obvious problem is the need to prove ideas, but this is where test facilities such as the Conoco sponsored Orkney Water Test Centre are invaluable. The provision to vendors of side stream facilities for equipment testing is another useful concept to support vendor equipment development.

PLANNING FOR FABRICATION AND INSTALLATION CONTRACT

29. Fabrication and installation contract competition is seen as healthy. Careful planning in the early stages of a project is necessary if fully competitive contracts are, in fact, to be achieved.

30. Fabrication methods are ideally set out in the basis of design documentation, before then, though, all the aspects that affect competitive bidding need to have been identified. This is best achieved by fabrication and installation studies during Project development planning. Commissioning a selection of contractors to give a cross-section of methods is a good idea to determine requirements.

31. A good example of providing flexibility is again from Murchison, but is still relevant today. At the time of Murchison only one company could make an offshore lift up to 3,000 tonnes. The MSF comprised two pieces, each of 2,000 tonnes. A two piece lift would be advantageous, it was reasoned, but having only one contractor capable of bidding was not acceptable. It was decided therefore, to construct the MSF in four pieces so that a number of installation contractors could quote realistically. However, so that advantage could be made of a two piece lift, the design was arranged so that two quarters could be joined together easily in the fabrication yard. Joining such large items together needed to be preplanned and designed to avoid a potentially very expensive exercise. As it happened, the two piece lift turned out the cheapest and that was the way we proceeded.

32. This example, although using a rather major piece of work, does show that the design has to consider the contract competition strategy which has to be identified early to be successful.

33. As offshore crane vessels grow, which makes larger modules possible, the question of yard capacities to build them efficiently then becomes a problem. Quay capability, yard cranage sub-contracting intentions are all going to influence a contractor's ability to compete. In order to build complete modules in minimum time and cost the advantage of undercover working needs to be considered. Undercover working offers considerable advantages in efficiency which contractors should be able to pass on by lower prices.

34. As equally important as the award to the prime contractor, is the provision for bidding to subcontractors. A design should lend itself to pieces being subcontracted. If subcontracting of pieces is provided for, the prime contractor should see benefits that he can pass on. The operator also has the opportunity to directly pre-contract and free issue to main fabrication contractors. Feasibility of this is greater today with the higher quality design available particularly the clash-free aspects of CADD. When backed up by good on site quality control, problems in fit-up of major pieces should be minimised. Substantial cost savings are then theoretically possible because of the potential competition from small contractors, who with considerably lower overheads, can provide lower prices. Obviously to achieve such benefits, emphasis has to be on the very early planning and careful site organising.

CONCLUSION

35. Planning effort in the early stages of a project offers the best opportunity to reduce project cost and schedules and produce economically viable projects. Innovative technology and project management concepts are ways by which cost and schedules may be reduced. The risks that

are taken by accepting new approaches have to be well understood and controlled. Usually small steps in technology can prove very rewarding, too large a step forward in technology can prove very costly. The rewards have to be balanced against the risks. This is particularly so as projects today are less tolerant of problems than they were a decade ago; it is therefore important to have thorough planning, risk analysis and then manage the project to minimise the possibility of cost or schedule overruns as far as possible.

36. Competition in various forms can be a useful tool to help plan the objectives of low cost, low risk, short development schedules. The use of competition to study options helps to obtain that little extra from people that makes all the difference in the early phase of a project as it does at any time.

37. Study competitions with design contractors, again achieve just that bit more that makes all the difference to the plans and a tremendous difference to a final development economic viability. Equipment suppliers should be encouraged to be innovative with smaller companies possibly entering the market to provide more competition. Two of the largest cost areas of a North Sea Project development are fabrication and installation, competition in these areas is essential. This is more likely to occur when early planning of the competition has been carried out. Such early planning of competition has the potential to save considerable sums. Finally, every project should plan to be better than the last and better than what other operators are doing; so we then have a healthy improving developing environment that challenges and demands better. In such an environment the North Sea can continue to prosper as it passes into maturity and smaller, less attractive reservoirs may be developed even with the low oil prices of today.

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3. Hidden benefits of cost reduction

T. S. RADFORD, MA, Barclays Bank plc and Institute of Petroleum

One does not have to be a specialist in Offshore Engineering to be aware of the changes that are taking place in our industry. Each new platform is of a lighter and simpler design than its predecessor, fields are brought into production more quickly with fewer offshore man-hours and the operators are always "on schedule and within budget".

The reasons given by the popular press for this trend usually centre around the sudden sharp fall in oil prices in 1986, but the motivation to reduce capital costs has always been there. The movements in oil prices have only served to confirm the pressures which already existed.

In the mid-1970's, and especially after 1979, the major pressure was to move projects forward quickly and, in the UK at least, generous levels of uplift allowance against PRT reduced the pressures to minimise capital costs, replacing it with time pressure.

Much as one is tempted to describe the changes since those days as a "revolution", I think "evolution" is a more suitable word and Mr. Doets gave examples of how jacket design progressed towards lighter structures with fewer members. The degree of challenge felt, by those who are actively engaged in new projects today, is just as great as it was ten years ago. The concepts may be different and the detailed problems to be solved are the same ones, but the pressures are as great. Engineers, will have more sophisticated tools at their disposal, (How many had a PC on their desk in 1978?), and materials science, control technology, subsea equipment, and so on, are all ten years more advanced. The world has changed, but the fundamental objectives have not. These might be stated as "To get the oil or gas out of the reservoir and into the tanker or pipeline, in a safe manner, at best possible profit to the project".

Cost Reduction in Offshore Engineering. Thomas Telford, London, 1988

Similarly, in the financial world, there have been many and fairly rapid changes in the last few years. Graham Hearne, in his opening address, referred to the current resistance of investors to raise fresh equity for the exploration and production companies, but that is only part of a larger and more complex picture. In project finance, however, our fundamental objectives are still much as they were "To find ways of lending to sound borrowers, at minimum risk and maximum return on capital".

Of course, the degree of risk which can be taken is limited because the money, which the banks lend to projects, they have had to seek on deposit. The best we can hope for is to achieve a slightly higher return from interest and fees, than in the case of a guaranteed loan. In project finance, there is usually no opportunity to participate in the upside rewards if the project exceeds its objectives, but the consequences, if the project were to fail, would be a direct loss. This risk aversion is why we would not finance exploration or appraisal drilling on a project basis and also the earliest offshore development projects in the UKCS were considered in the same category.

Fairly soon, however, limited recourse financing became available for development projects, adapting to the UK, techniques which had been used, in other areas, for some time and taking advantage of the growing market for syndicated loans in Eurodollars which resulted from the, then, rapidly rising surpluses in the OPEC countries. These surpluses came from the same rise in oil prices which made the offshore projects, being financed, so attractive in the first place.

This increasing market in limited recourse finance attracted a large number of banks and, for a while, the competition was intense. Some unwarranted risks were taken, especially onshore USA, with the inevitable result that a few of the major banks took heavy losses as well as a relatively larger number of the smaller local banks in Texas and Oklahoma. On the international scene, at that time, we saw some projects financed on the basis of unrealistic oil price expectations or with the lenders accepting levels of risk or new areas of risk which exceeds our normal criteria.

The worldwide market in limited recourse project finance for the oil industry, especially offshore, today continues to be competitive, despite the fact that some of the banks which were most active in the early 1980's have since ceased this type of business. Now, as a result of there being relatively few projects compared to the early 1980's, it is still possible to finance a project on terms which are generous compared to those offered in earlier years. Those banks, which are still active in this field, have maintained consistent policies throughout the period and kept their teams of specialists and engineers intact. This is not to say that their techniques and the details of the financing agreements have not evolved. We have adapted to the changing times and make use of the various techniques of hedging risks, such as currency and interest rate changes in a manner tailored to each project, as well as adapting the various financial instruments which may be applicable.

This is an international market and whilst each country has its own features and legal apparatus, the underlying principles do not change. Thus, to give only one example, in the USA, interests in leases and mineral rights are considered to be real property and are more easily traded, whereas here it is only an interest in a licence or the proceeds from a sales contract which can be pledged as security. These differences cause changes in the documentation, but are not usually a major problem in setting up a financing.

In either case, because the banks do not invest equity in a project but only lend against the expectation of being repaid according to a schedule, the borrower is expected to provide equity funds to cover the first and/or the most risky parts of the venture. The lenders expect repayment out of the most secure part of the cashflow, in the early years, and they would only allow the borrower to extract profits after they are assured that the repayment schedule can be met in full. The borrower usually has to pledge all of his interest in the project assets as security for the loan.

The mechanism by which these controls are exercised is usually a cover ratio, defined as the Net Present Value of future cashflow divided by the loan outstanding. Exactly how these are calculated depends on the nature of the financing, but the discount rate is typically higher than might be used, internally, for a company's own evaluation.

These cover ratios may control a variety of features in different ways. Thus, at one time, the ratio might limit drawdowns on the facility to those which did not cause the ratio to fall below, say, 1.75. Elsewhere, in the agreement the rate at which repayments are made could be determined by reference to a table in which a higher ratio allowed a lower percentage of the cashflow to be required for debt service. There are usually numerous other covenants and conditions which restrict the borrower as to what he can do to control his interest in the project. Exactly what it costs the borrower in fees and interest rate margins (percentage over LIBOR), depends on the way he wishes to share his risks with the lenders or other parties. This much is fundamental to project finance and, in some form, has always been the case.

What is relatively new is the range of risks which can now be singled out for special consideration and the corresponding detailed knowledge of the project which is entailed. By reducing the risk in certain areas, as a result of awarding a lump sum contract, for example, or agreeing to accept the cost of budget overruns in other areas, the borrower can optimise his position. The banks have the facilities to arrange ECGD cover (or the equivalent in other countries) for those parts of a project which may be eligible. Similarly DTI guarantees under the Shipbuilding Mortgage finance scheme can be arranged, if the project qualifies. The forward, futures and options market may be employed to cover currency or product price risks in the shorter term or over a critical period.

There are also a large number of different ways in which the borrower's requirement to provide equity may be met. These may incorporate some of the new capital instruments, whilst the funding actually is provided by the lending banks, or other parties. This mezzanine finance i.e. half way between Equity and Debt, can expand the range of possibilities for a borrower. Obviously, the more complex arrangements take longer to set up and the earlier that the lending banks become involved in the project, the better. Similarly the closer that the banks can work with their customers, the better they can structure a financing to meet their objectives.

In the past, for relatively simple financings, the borrowers tended to proceed with their project planning and then select one out of a group of competing banks at a fairly late stage with only a few weeks to complete the deal, and syndicate it amongst the other banks, before signing, just prior to the first drawdown. This may not always be the wisest course and, by maintaining the right relationships with potential lenders from an early stage some cost reductions may be possible in the long run.

How then, does this fit in with the cost reduction philosophies which we have heard discussed already this morning and the various techniques which will be discussed later in the conference?

Obviously, if the new feature of the project significantly increases the actual risk of failure, reduced throughput or cost overruns, then there will be a corresponding penalty in increased financing costs or limits to the size of the available loan. Any combination of features that give rise to such a penalty would normally be eliminated at an early stage. We have just heard from Mr. Sanderson that the costs are only one element in a complex economic balance and the choice of financing options need not be seen as separate from the other aspects of development strategy.

Other cost reductions might be considered neutral to the project finance. These might be such things as the use of larger modules and integrated deck structures to take advantage of the greater lifting capacity of the new generation of crane vessels. Offshore hook-up time is reduced, giving a second order saving. Many more examples will be quoted in the course of the day. Here, the capital requirements are reduced, so less financing is required but the overall risks are, otherwise, much the same.

The more interesting class of cost reduction features are those that, of themselves, reduce risks as well. It could be argued that the completion schedule is more secure with a lower probability of delays, that the costing can be more tightly controlled and fixed price contracts obtained at rates which do not incur penalties, if these features are used. If that is the case, and if these benefits can be determined with enough confidence by the time of the signing of the financing, then they will have contributed to the reduction of overall risk. I am sure that some of Mr. Hall's techniques for employing competition internally, and between contractors will bear fruit in this way. It is the change in way that the project is organised which makes it more secure.

There are other ways in which costs may be reduced and the overall project made attractive to lenders. If (again at the critical time) there is a well defined project scope with an organisation in place with fixed price contracts, either signed or close to it, covering the majority of the budget, this is itself a positive feature. The lenders have always expected to be informed of the progress of contracts and where the right control mechanism is seen to be in place from the start the level of perceived risk is lower.

Some unconventional projects may be seen to be more or less acceptable because of the timing differences. In a conventional field development, the operator and the co-licencees commit to a major project and immediately need to seek assurances from each other as to their ability to finance their share of the costs. This is understandable because the penalties for a default are severe and a defaulter throws an increased burden on his partners. At the conceptual stage, their obligations are mainly to each other since no funds are committed at that stage, but it can lead to an early move to try to secure financing for the project. If, for example, the operator were to choose to use a contractor for the development and operation on a tariff basis, the whole economics is changed, with minimum call on the licencees but the contractor seeking finance. His timing could be geared to other factors and controlled by his contract with the licencees. The options open to the contractor would be a function of his overall corporate situation and he might be in a position to control certain risks in a way in which a group of licencees could not achieve. This could be an interesting new development and lead to opportunities for the exploitation of many of the smaller reservoirs in the North Sea.

We should not forget that there are some companies who have been employing a cost reduction philosophy or something that looks very like it for a long time. The first oil ashore from the UKCS did, after all, come from Argyll field and not Forties. That project was seen, at its inception, by outsiders, to be a risky venture and all credit to Hamilton for making into one of the most profitable in the UKCS.

A few years later, Conoco's development of Murchison was a major step away from the dependence on a prime contractor with the duplication of design effort that arose in some areas of the preceding projects. Also their use of a simulator for the training of operators and the proving of control systems resulted in cost saving both in hook-up and operations. Parallel savings were also seen in their drilling operations. Some of these cost savings were evolutionary and others more radical, but they do illustrate that cost reduction is not new concept or confined to the present generation of projects.

The "Hidden Benefits" of cost reduction relate to the ephemeral nature of building confidence and conveying it to others, in this case the banks who are being asked to finance your project. We like to see conventional techniques employed in a project where they increase the overall security but the reduction in costs can, in many cases achieve this same end by the way in which it is implemented. In that case the reward will be the greater because it will allow for more favourable borrowing terms as a result of the greater confidence which can be held in the successful outcome. The banks are still keen to lend to soundly based projects and the better we understand the details, the better we can meet your corporate objectives.

4. Weight/cost reduction philosophies

R. O. HINTON, MA (Cantab), Taylor Woodrow Offshore Ltd

SYNOPSIS. Taylor Woodrow Offshore has been active in topsides weight reduction since 1983. Initial studies of drilling facilities have subsequently been expanded to cover more general topsides areas. This paper shows weight and cost reduction potential by a selection of examples.

INTRODUCTION

1. Weight reduction which gives no resulting cost benefit is something of an academic exercise.

2. However cost reductions identifiable by application of weight reduction methods are as useful as cost reductions identifiable by any other means.

3. This paper is intended by means of specific examples to address platform cost reductions achievable in parallel with topsides weight reduction and generally identified by seeking weight reductions in the first instances.

PLATFORM WEIGHT AND COST COMPONENTS

4. Typically platform topsides are made up of the following components:

Discipline	Weight %	Cost %
Structural	55	25
Equipment	25	33
Piping	8	16
Electrical	6	8
Instruments	3	15
HVAC	3	3

KNOCK-ON EFFECTS

5. The knock-on effect from the "Primary Process" is worth considering next. Primary Process in this instance includes drilling, production and injection.

6. One could say that anything not actually performing a "Primary Process" function is an "overhead" to this "Primary Process". Such "overheads" include:

Power Generation
Other Utilities
Accommodation
Module Space
Supporting Structure and Substructure

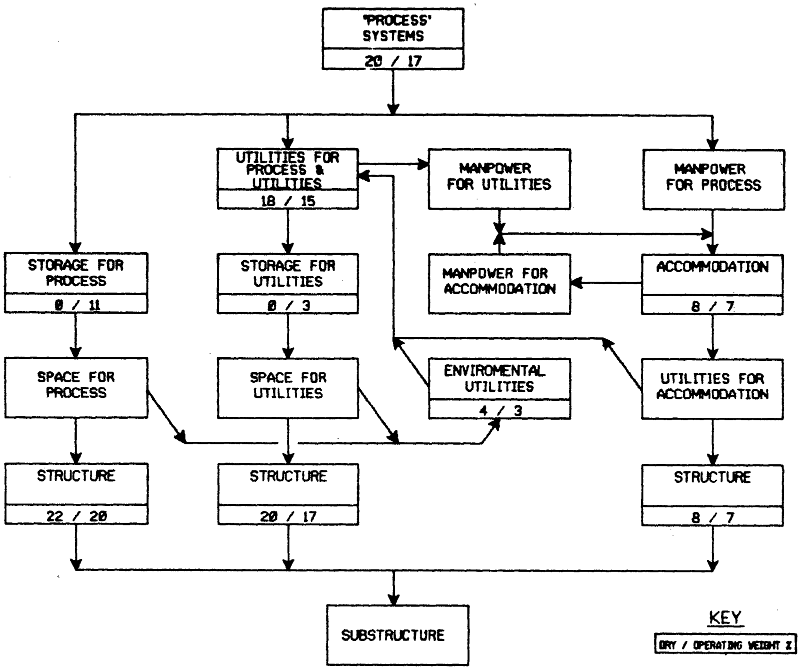


Fig 1 Knock-on effect from 'process'

7. The chart above gives a simplified interrelationship of platform facilities. From this various points may be made.

9. The Primary Process itself typically accounts for some 20% of dry weight or some 17% of total operating weight.

10. The primary utility is electrical power generation which typically accounts for half of the total utilities weight.

11. You may have noticed that storage for process makes up 11% of operating weight and over half of this is for drilling.

12. Accommodation takes up around 8%.

13. Supporting it all is some 50% plus overall module structure with substructure, depending on environmental conditions, keeping the topsides above the waves.

14. Any saving in "Primary Process" may have a significant knock-on saving in the "overheads" and any excessive provision of "overheads" is wasted money.

TIMING OF WEIGHT/COST REDUCTION INITIATIVES

15. Timing of weight/cost reduction initiatives is crucial.

16. It is clear that to obtain the full benefits both the saving itself and the knock-on savings must be achievable. As can be seen from the curve below, costs rise dramatically as the design is detailed and procurement commitments are made. Costs of change rapidly rise to exceed potential savings so savings are lost. If for example a layout improvement is achievable during the detailed design, it is very unlikely that the module size will be reduced - thus the structure and substructure savings will not be realisable.

17. It is therefore essential that potential benefits are actively sought and selected early.

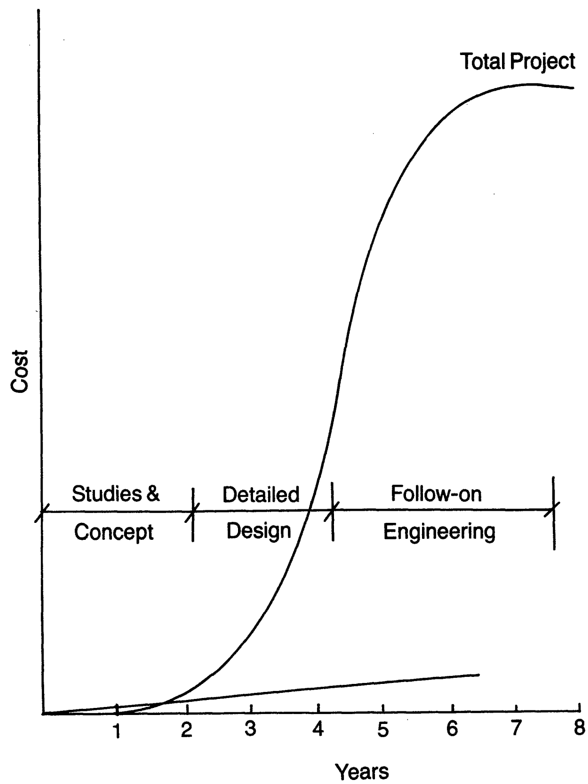


Fig 2 Project cost curve

18. Looking on the positive side, projects recently completed may have had at most up to 12 months total front end and preliminary engineering with perhaps 2 years plus of detailed design. Now the trend seems to be towards more extensive preliminary work - possibly with a reduced detailed design programme.

19. Thus more optimisation may be carried out while the design is still deliberately kept fluid. This allows more design loops and the incorporation of knock-on benefits into the design.

20. Because the design of an offshore platform is a highly interdependent activity, it may be beneficial at the preliminary engineering phase to develop several design options in parallel and to analyse relative weight and cost benefits between the options.

21. A series development covering required options may be too slow and may fail to highlight the best combination.

PRESSURES AND INCENTIVES

22. Pressures and incentives for the design team are determined by the project programme and contract structure.

23. Optimum weight and cost solutions may require additional design effort and may impact adversely on individual design discipline schedule, manhour or weight budgets. It is important therefore that the design is viewed as a whole and worthwhile potential benefits are not driven underground through rigid application of schedules and budgets particularly during preliminary engineering. Adequate time and resources should be built-in to the initial programme to allow for successive design optimisation loops.

TARGET AREAS FOR SAVINGS

24. Weight/cost reduction philosophies do not generally provide design solutions rather they question the design, allow identification of target areas and indicate possibilities for savings.

25. This paper does not aim to go through a great check list of generalisations, but rather to focus on a few specific examples. The table below gives main target areas and examples are taken from within those marked*.

- Process Alternatives*
- Standby Equipment
- Process Trains
- Drilling Storage*
- Production Storage & Inventory
- Utilities Ratings & Integration*

- Manning Levels
- Layout Optimisation*
- Structural Optimisation
- Materials

Process Alternatives:

26. Turboexpanders have long been used onshore for energy recovery and refrigeration. Their use offshore can also bring substantial benefits as has been demonstrated in a study by M W Kellogg - who are now serving the offshore market within the Taywood Kellogg Joint Venture.
27. In this study the advantages of using reservoir energy to separate hydrocarbon condensate from natural gas streams have been demonstrated. The use of turboexpanders provides sufficient refrigeration to obtain high condensate recovery in addition to valuable energy.
28. Three process alternatives were considered namely:

- Conventional flowscheme with freon refrigeration
- Expander flowscheme with conventional stabilization
- Expander flowscheme with stripper stabilisation.

29. These options were developed through process, equipment and layout design, and weight & cost effects quantified.

	Base Case	Expander Case	Expander & Stripper Case
Estimated Weight Difference - tonnes	0	-300	+400
Estimated Space Savings - sq m	0	140	240
Day 1 Energy Consumption kW/BPSD	.787	.789	.704
Condensate Recovery BPSD	100450	103550	104800

30. Overall effects are shown in the summary table above. It can be seen that the best weight saving is found in the expander case, but more space and energy are saved with the stripper option - which also yields more product but with a significant weight penalty from the additional waste heat recovery and stripper column.

31. Capital costs show a £4 million reduction for the expander case and a £2 million increase for the stripper.
32. Further analysis will show what the optimum solution would be but the search for weight/cost reduction has identified the possibilities.

Drilling Storage

33. Storage of drilling consumables needs to satisfy safety and non-supply criteria.
34. This should lead to a reasonably uniform or consistent succession of design solutions in terms of storage provision. However, it would appear that a wide range exists.

	Liquid Mud Storage cu.m	Bulk Mud/Cement Storage cu.m
FIXED PLATFORMS		
Oseberg A	900	700
Magnus	620	810
Gaviota	400	400
Tern	400	330
Cormorant N	400	350
Rough	300	350
Tartan	250	200
Current N Sea	470	280
Current N Sea	420	400
SEMI SUBMERSIBLES		
Bluewater III	190	200
Ocean Ben Loyal	220	490
JACK UPS		
Dyvi Sigma	210	200
Gilbert Rowe	230	190

35. Storage equipment itself may not cost very much but it requires significant space and structure to support it offshore.
36. We are looking here at a range of weights stored between 600 and 2000+ tonnes for liquid mud and bulk mud and cement only.
37. In addition some designs call for dedicated storage for say brine or drillwater while others play tunes on reserve mud tanks to save space and weight.
38. While the two current North Sea projects here show some consistency on liquid mud and bulk storage, one operator is calling for over 250 cu.m of dedicated brine storage (not shown in the table) while the other is not calling for any.

39. Possibly there are good economic reasons but in the quest for weight/cost reduction this should be examined. Does the worst non-supply/drilling programme scenario still allow spare reserve mud storage when brine is required? It could save say 100-200t of module steel depending on the configuration, in addition to reducing the maximum design load on the substructure by approximately 500 tonnes.

Utilities Ratings and Integration

Selection of Medium Voltage Level

40. The normal platform medium voltage level is 415V but 600 volts for AC drives offers weight and cost advantages. It is also the voltage used for drilling SCR's.

41. By use of 600 volts, cable weights/costs are reduced by some 30-40% and drilling power transformers are reduced or eliminated depending on the configuration. In certain cases motor frame sizes may be reduced and the size break to HV goes from 150 to 200kW.

42. For the drilling facilities power system alone on a platform recently studied this represented a 20 tonne saving. For a large production platform this could well rise to some 50 tonnes.

43. This is possible because MV cables are rated up to 1000V as are motors and switchgear.

Utilities Integration

44. Utilities Integration appears to be becoming the norm in new platform designs for several reasons.

- With larger integrated deck facilities, offshore hook-up is much reduced and platform facilities are quickly available to service drilling. Thus the main traditional benefits of dedicated utilities such as drilling diesel generation and compressed air are no longer relevant.
- Significant weight and space savings may be achieved say $\underline{u}$ 400t for integrated power generation. These depend however on the drilling programme duration, production load profile and machine frame sizes for particular loads.

Layout Optimisation

Module Layouts

45. Layout optimisation is part of an iterative design optimisation process and radical benefits can only be achieved in the initial study and conceptual engineering phases.
46. All the space in a module is available and should be fully used. A recent TWOL study achieved significant module size reduction principally by appropriate level selection within a normal overall module height. This allows more usable floor area per unit module volume and improved equipment interconnections from vertical proximity. An elevation is shown below. (See Fig. 4)
47. The resulting module volume reduction is shown below and amounts to some 30%.

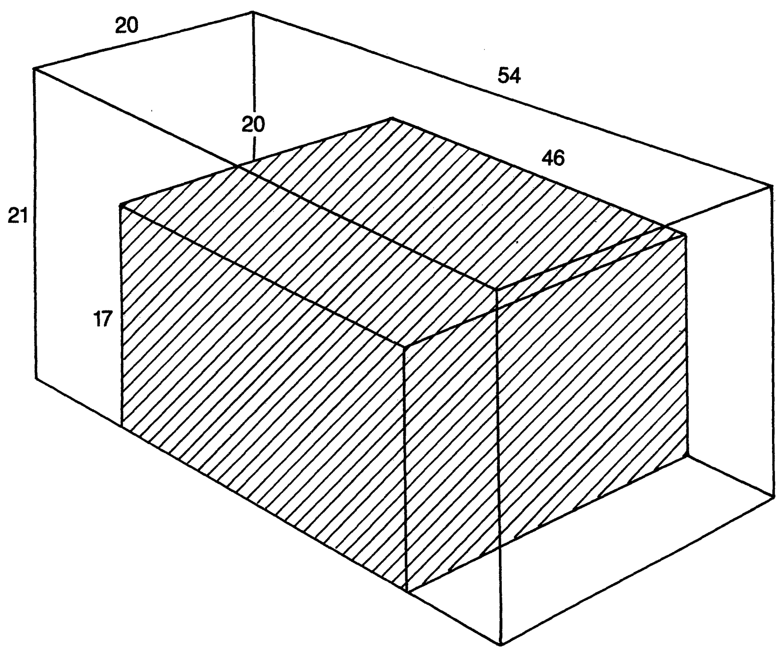


Fig. 3 Module Size Reduction

48. This is equivalent to a saving of some 12-1400 tonnes of module structure for these overall dimensions.

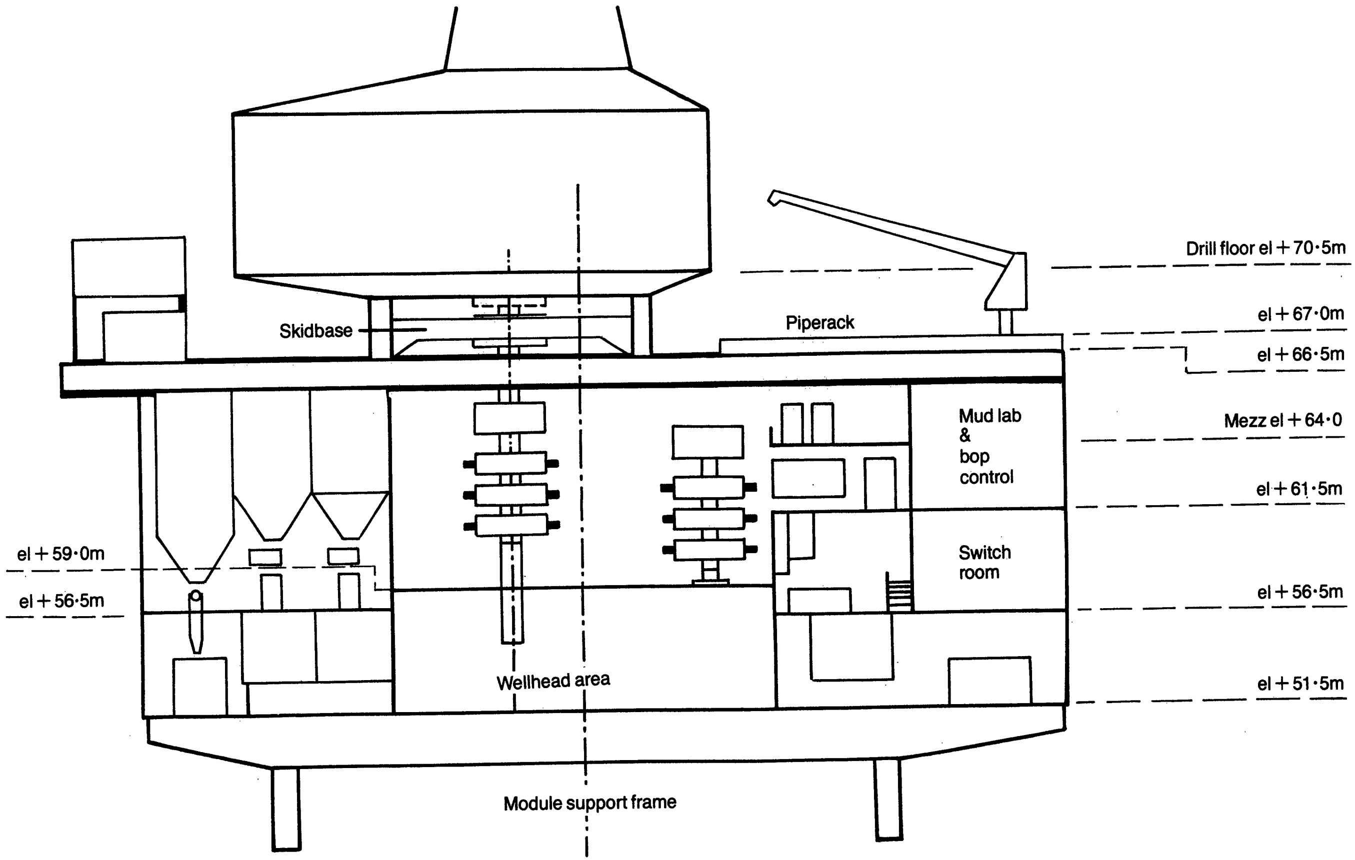


Fig. 4 Module Elevation

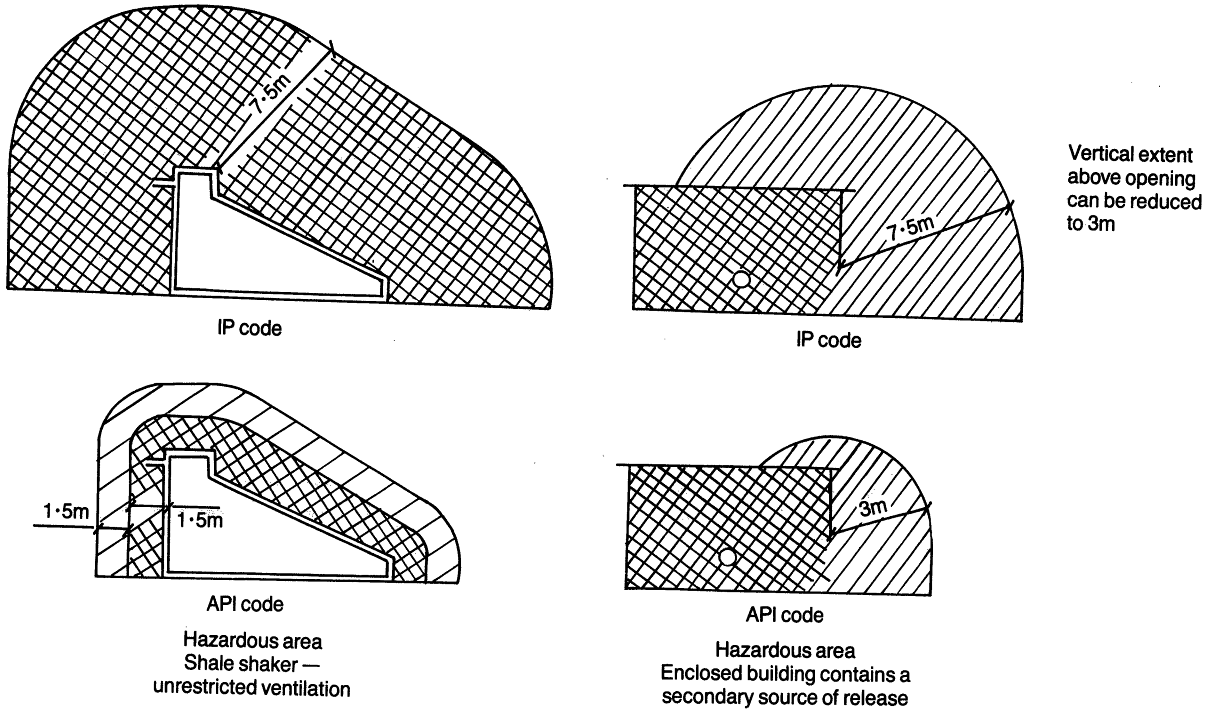


Fig.5. Typical applications of IP and API codes

Equipment Integration

49. In addition to more complete utilisation of module space, individual equipment items may also be integrated to provide more compact overall configurations. An example recently studied by M W Kellogg allowed a four stage refrigeration circuit using five exchangers, four drums and a separator to be combined into a single combined chiller/flash drum.

50. This allows substantial space reduction and also increased shop and reduced yard fabrication. In addition, reliability is improved.

51. This approach has potential application for example in gas condensate recovery.

Hazardous Area Classification

52. Both IP and API codes are acceptable for UK installations. Their requirements differ as the two examples given show. (See Fig. 5)

53. A range of weight/cost reduction possibilities opens up if API code is selected - layout constraints may be eased e.g. air intake/engine exhaust locations, and industrial grade rather than flameproof equipment may be selected in certain instances.

54. In a recent study TWOL concluded that a minimum facilities satellite platform topside would change from open to enclosed design if IP code were used rather than API.

SUMMARY

55. By looking at five particular examples taken from four of the 10 principal target areas selected, this paper has identified potential savings of some 2250 tonnes for a typical drilling and production platform topsides, which could amount to a cost saving approaching £20 million overall.

56. A methodical approach using a weight/cost reduction philosophy check list to highlight all potential savings would realise more. In a recent extensive industry study potential reductions of 28% weight and 18% cost were identified for a benchmark platform with 26000 tonne topsides, giving rise to a cost saving approaching £90 million.

57. Weight and capital cost are not however parameters to be viewed in isolation. Safety must be maintained and operating and maintenance costs, reliability, availability and manning levels must also be taken into account to achieve minimum overall cost.

5. Cost effective structures for the North Sea

N. J. HEAF, Atkins Oil & Gas Engineering Ltd

SYNOPSIS

The present lower oil price regime has forced both the offshore operators and design contractors to look more critically to the costs of offshore oil facilities. Since the largest individual proportion (30%-40%) of the cost is in the structure of such facilities, a large burden of responsibility for identifying and developing cost effective solutions has fallen upon the offshore structural engineer.

INTRODUCTION

Several areas of potential cost saving have been investigated which can be categorised as follows:

- Changes of concept; for example, from fixed to floating structures or from above water line to subsea completions;

- Changes of configuration; for example, from launched to lifted jackets or from modular to integrated deck construction;

- Use of new construction and installation equipment; for example, heavy wall tubulars and larger capacity lift vessels;

- Change design philosophy; rationalisation of contingencies and safety factors;

- Changes to detail design to produce a reduction in lifetime cost.

AREAS OF COST EFFECTIVENESS

Cost effectiveness of structures may be considered under the following headings:

Heading	Examples
* Concept	- Fixed - Floating/Mobile - Subsea
* Configuration	- Launched/Lifted - Integrated/Modular - Manned/Unmanned
* Materials	- High Strength Steels - Composites
* Fabrication/ Installation	- Heavy Wall Tubulars - Rational Defect Assessment - SSCV Installation Vessels
* Design	- Philosophy - Details - Lifetime Cost

CONCEPT DEVELOPMENT

Concept development should be considered in the context of the different types of offshore development options as follows:

* Fixed Installations
  - Majority of offshore facilities are fixed (95%)
  - Strong track record
  - Low risk
  - Little opportunity for innovation
* Floating/Mobile
  - Lower capital expenditure
  - Higher maintenance costs
  - Change of use (exploration to production) leads to lower reliability
  - MODU and ship design rules are less rigorous than fixed platform criteria

* Subsea

  - High degree of innovation

  - Relatively lower capital costs

  - High service/workover cost

  - Dependent on infrastructure of fixed or floating platforms (infill)

METHODS OF CONCEPT ASSESSMENT

It has in the past been extremely difficult to select a particular concept at the feasibility stage of field development due to the large number of dependent unquantifiable factors. For example, it is virtually impossible to predict fabrication or offshore equipment hire rates with any certainty in advance.

Concept assessment can be undertaken by two methods:

* Review Historical Out-turn Costs

  - Reliable database

  - Tends to perpetuate own company methods

  - Difficult to incorporate change

* Cost Forecasting Models

  - Reliable multi-company database

  - Objective assessment

  - Methodology for costing innovation

  - Alternatives can be evaluated rapidly

  - Links between capital, operating and abandonment costs

The first method has traditionally been used in the past. However, with the rapidly developing technology brought about by the oil price drop, cost forecasting models are becoming more popular for their ability to cost innovative technology, stream- lined project management and alternate contract strategies.

A capital cost forecasting system, which incorporates an historical cost data base, may be used to make objective comparisons between development options and to quantify the sensitivity to price variations. In the selection of a particular concept, there is a strong incentive to minimise the risk of large cost overruns. For example, those due to novel technology requirements. Therefore, concept selection will tend to favour tried and tested solutions to the elimination of new concepts, even if they have high cost saving potential.

Changes in configuration, within a particular concept, are very much an acceptable method of cost reduction, since they generally do not involve novel technology and the cost savings can be relatively accurately identified.

CONCEPT DEVELOPMENT

A large majority of UKCS field developments in the past have been utilised fixed steel sub-structures and it is likely that these will continue to be a prime candidate for future developments in water depths up to 200 m.

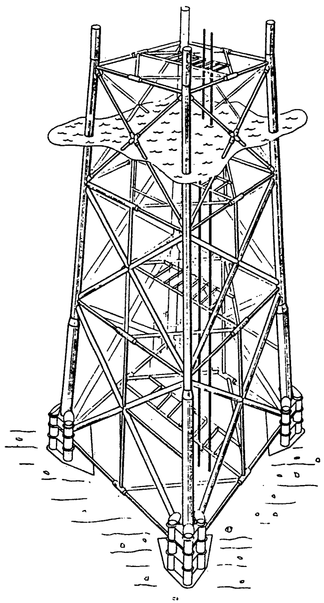
The requirement for cost reduction to accommodate the reduced oil price has prompted the development of lightweight jacket designs.

Figures 1, 2 and 3 show a typical concept development and refinement for lightweight liftable jackets. It illustrates the basic concept, which arose from the availability of the new generation of heavy lift vessels and its refinement to accommodate larger topsides, greater water depths and easier fabrication and installation.

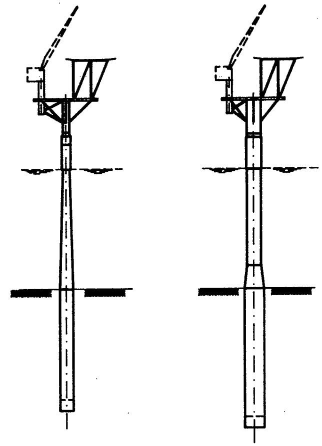
New materials, new construction techniques and new construction equipment are continually being suggested and those that are cost effective will gain the appropriate recognition and use. The role of those making engineering decisions in this case is to understand the implications and consequential results of these new items and to suggest to suppliers how their use can be optimised.

Discipline Potential for Topsides Weight and Cost Saving

The potential by discipline for cost and weight savings on topsides is given below:



LIGHTWEIGHT LIFTABLE JACKET
FOR CENTRAL NORTH SEA



SINGLE WELL CAISSON

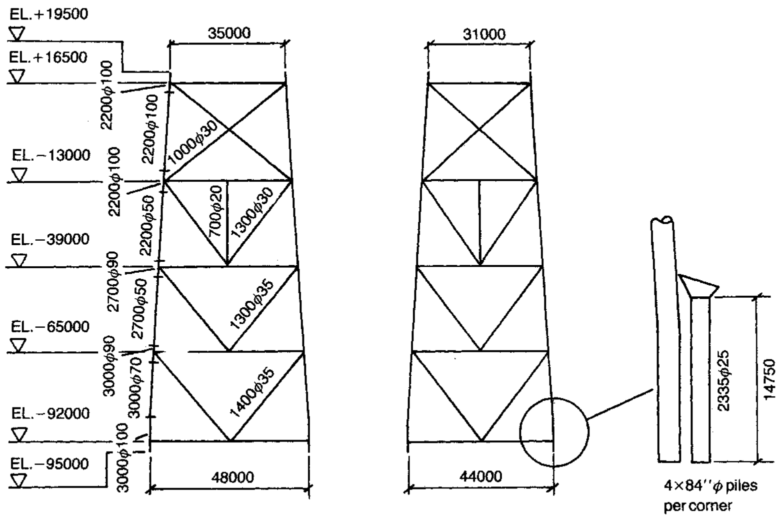
FOUR WELL CAISSON

PLATFORM DATA

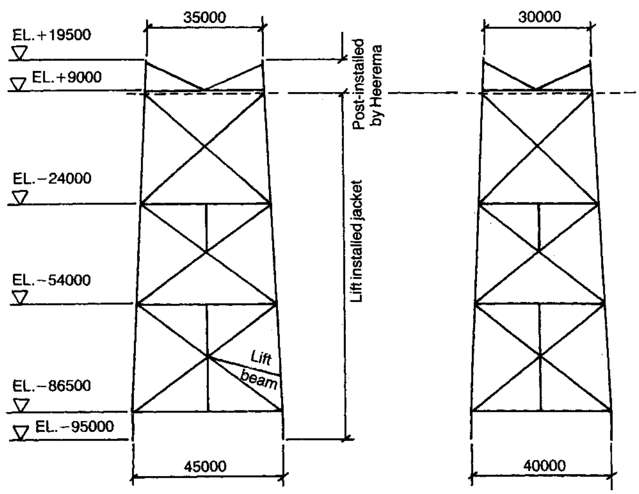
LOCATION:	SOUTHERN SECTOR OF UKCS
WATER DEPTH:	30 m
No. OF WELLS:	SINGLE WELL OR FOUR WELLS
PILE PENETRATION:	30–35 m
OPERATIONS:	UNMANNED WITH TEMPORARY SHELTER FOR 4 PERSONNEL
TOPSIDES:	OPERATIONAL WEIGHT 174T SINGLE WELL, 231T 4 WELL
DESIGN LIFE:	10 YEARS – SINGLE WELL, 20 YEARS – FOUR WELL

CAISSON TYPE MINIMUM FACILITIES STRUCTURE
FOR SOUTHERN NORTH SEA

Fig.1. Minimum cost platform concepts

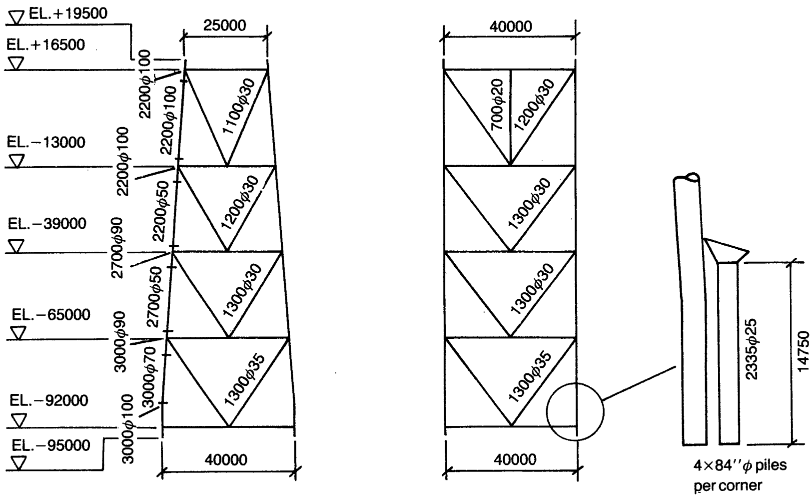


95m – depth jacket concept for
DB102 or M7000 installation

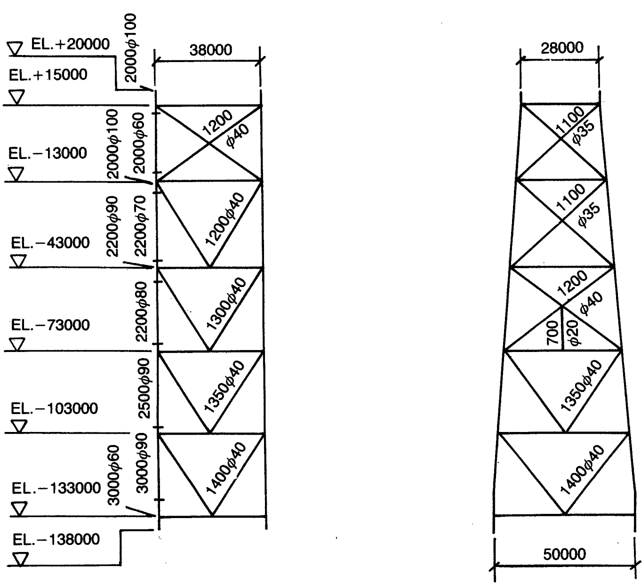


95m – depth jacket concept suitable for
Heerema Hermod installation

Fig.2. Original lightweight liftable jacket concepts



95m – depth jacket concept for 21000 tonne integrated deck and DB102 installation



Parallel leg loadout concept (138 m depth)

Fig.3. Development of lightweight concept to assist loadout and/or increase water depth

	Weight Saving		Cost Saving
Bulks	14%	)	
Equipment	17%	)	31%
Structure	69%		59%
Other *	-		10%
Total Saving	28%		18%

(* Insurance/project management, etc.)

Ref. Study on topsides weight reduction
Global Engineering, 1987

The evolution of topsides design to correspond with a lightweight jacket is shown in Figure 4.

New construction equipment includes:

* Large/up-rated SSCV's

  - Heerema Hermod (4000/5000 sh t)
  - McDermott DB 102 (2 x 6000 tonne)
  - Micoperi M 7000 (2 x 7000 tonne)

* Underwater pile driving (vertical piles)

* Diver/ROV operated grouting

* Mechanical grout seal

* Hydralok pile connection

The common attribute of these is that their use almost always allows a reduction in steel required for temporary conditions. This results in a design, which is more closely governed by the in-place or in-service conditions.

A review of the use of new and/or lighter materials has lead to the following conclusions:

* Does not directly reduct cost

* Can lead to cost reduction through reduction of support structure and increased competition

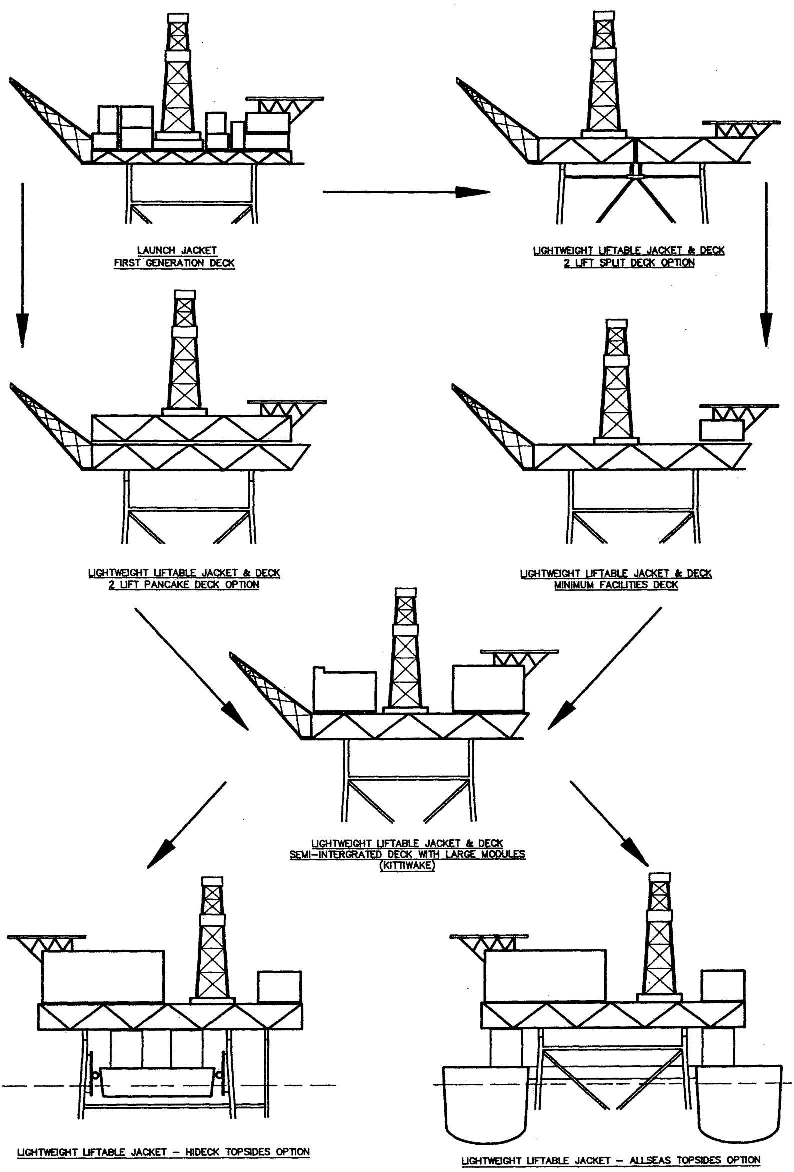


Fig.4. Topsides concept development to minimise offshore HUC

* Effect is approximately 1:4 (ie. 1 tonne of structure saved for every 4 tonnes of equipment weight reduced)

* Ref: Study on lightweight materials for offshore structures. Fulmer/Wimpey 1987

In summary:

* Lightweight liftable jacket can lead to significant cost savings - estimated to be £10 to £15 million for Kittiwake, and are therefore very cost effective

* Significant savings in fabrication and installation schedule

* Lightweight philosophy can have beneficial effect on topside weight and cost even though this is not required to achieve a lifted a jacket

* Important to keep installation contract competitive (ie. including Heerema)

* Now tried and tested technology - becoming standard industry practice

DESIGN PHILOSOPHY

Changes in design philosophy and rationalisation of contingencies is an area where governmental organisations, certification authorities, as well as design engineers, can all contribute to more cost effective offshore structures. Often the cumulative effect of a series of slightly over-estimated requirements and over-designed components can result in a significantly over-specified structure. A consistent framework for the solution of this problem needs to be developed and closely monitored for each project.

Recent studies have shown that a major proportion of potential cost savings are due to the reduction in support structure costs as equipment weights are reduced. Therefore it is important to:

* Reduce topside weights by consistent design philosophy

* Eliminate
  - Opinion engineering
  - Double safety factors
  - Unnecessary contingencies

* Use weight management to set and maintain targets

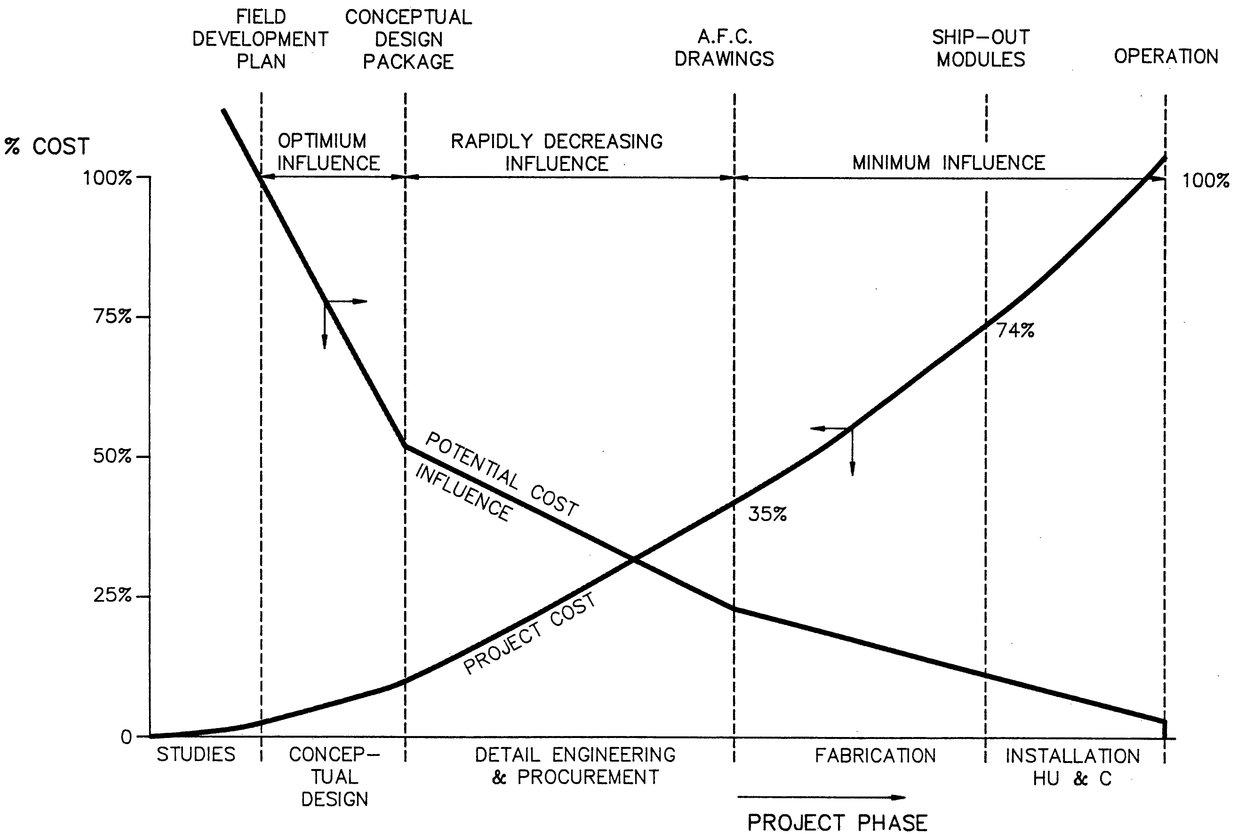


Fig.5. Offshore facilities typical cost curve (Fulmer/Wimpey, 1987)

DESIGN FOR LIFETIME COST

Finally, the quality of detailed design is critical in determining the requirements of inspection and maintenance of offshore structures and the selection of details which are fit for their purpose is critical in making sure that lifetime cost is minimised.

In this respect it is important to:

* Develop an inspection and maintenance strategy and use simplified details during the design in order to minimise inspection cost

* Identify repair options during detailed design

* Consider abandonment requirements

Figure 5 illustrates that the influence on the out-turn cost effectiveness reduces rapidly as the project moves from conceptual through to detailed design.

SUMMARY

In summary it may be stated that:

* Weight reduction leads to reduced support structure costs

* Cost effective structures are governed by in-place conditions

* Subsea/floating options have higher maintenance costs and may not be the most cost effective over the whole field life

* New construction and installation methods are more important than new materials

* Cost effectiveness is determined by concept choice and can only be marginally improved by detailed design

6. Platform monitoring as a tool for cost reduction

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BP International

Synopsis

Offshore platform design is more conservative than is the case for onshore structures. This is necessary because of the high cost of failure coupled with the considerable uncertainty in defining the applied loading and the structure's response. The best way to reduce this uncertainty is to monitor the actual behaviour of platforms.

The benefit of such monitoring can far outweigh its cost. With increased confidence less conservative designs can be produced without increased risk. Savings can be made both in modifications to the original installation and in the design of future platforms.

BP's Magnus Structural Monitoring system is an example. The system contributed 0.16% to the overall platform cost. The measurements so far have demonstrated that four extra wells can be drilled from the platform rather than as satellites. The potential saving between these alternatives is about 40 times the cost of the monitoring system.

Introduction

Offshore platforms are generally designed for more onerous loading conditions than are onshore structures. The degree of uncertainty associated with determining design loadings is much greater than in the case of onshore structures; at the same time the cost of remedying errors is very high and the potential consequences of structural failure are catastrophic. It is therefore understandable, indeed desirable, that engineers have tended to compensate for this uncertainty by introducing greater conservatism into design.

There are many sources of uncertainty in design predictions, but the major contributions may be summarised as follows:

- Statistical: how confidently can the design wind speed, waves and currents be predicted from a limited data set?
- Mathematical: how well can the conventionally used regular, two dimensional wave theories (such as Airy, Stokes, Dean) predict the surface profiles, velocities and accelerations of the real sea which is irregular and three-dimensional?
- Physical: how closely does the empirical Morrison equation, universally used to calculate the hydrodynamic loads acting on jackets, describe the real effect of waves on structural members?

There must obviously be some scope for reducing costs by improving confidence in the design predictions.

Platform Monitoring

The best way to improve confidence is by calibrating design against reality:- by measuring the behaviour of real structures in response to real environmental loading.

This is a straightforward objective; it is however anything but straightforward to implement. Table I shows a list - not comprehensive - of some jacket structures that have been instrumented for structural measurements. The most publicised of these are the Joint Industry efforts of the Wave Force Project (WP1 and WP2) between 1954-63 and the Ocean Test Structure (OTS) in the mid-1970's, but most of the major oil companies have instrumented one or another of their structures over the last 20 years.

The emphasis in all of these projects has been to prove that the platforms are structurally safe - and they have done so very successfully. However, once it has been satisfactorily demonstrated that the jackets' deflections and stresses are not going to be greater than those predicted in the design, there is less incentive to analyse the data further.

There are also practical reasons why platform monitoring data has not been used as fully as it might be, particularly in some of the earliest projects. Data recorders were erratic and required a good deal of maintenance - a fact which did not endear them to the platform operations staff. Analysis of the tapes was carried out onshore, so the operators saw no benefit to themselves. Data processing was cumbersome and expensive. Only a limited amount of useful data could be collected anyway in the handful of storms that occur in the typical one or two winters' operation of a system. There was no general consensus on how this kind of data should be interpreted.

The more recent projects have however overcome most of the earlier instrumentation problems. Since micro-processors have become ubiquitous it has been possible to carry out sophisticated data processing relatively cheaply. With the benefit of experience data interpretation has become easier, and a much better understanding has been gained of real platform behaviour. And all of the information points to the fact that these structures experience lower stresses than predicted from the enviromental criteria.

Although the cost and effort involved in a monitoring exercise is not trivial, benefits can be gained that far outweigh the cost. If a platform's behaviour and structural capacity can be established with greater confidence, in-service modifications may be carried out more easily. This is likely to become an important factor in the economics of smaller fields which are to be developed as step-outs from existing installations, requiring extra process plant and additional risers on the parent platform. Recertification can also be made considerably easier if a case can be presented to the certifying authorities for relaxing the original design parameters.

The general lessons learned about environmental loads and platform response will also benefit subsequent field developments. With a rational basis for revising the design parameters it should be possible to design lighter, cheaper structures with lower risk.

Magnus Structural Monitoring System

One of BP's recent experiences in platform monitoring, on the Magnus structure, is a good example of the above.

The Magnus field is situated 160km NE of the Shetland Islands, lying across Blocks 211/12a and 211/17a (fig 1). Oil was discovered in 1974. Because of the extent of the reservoir it would have been technically preferable to develop the field with two fixed platforms; the harsh environmental conditions however made this prohibitively costly. One central fixed

Table I: Platform Monitoring Projects

STRUCTURE	OPERATOR	DATES	WATER DEPTH
Cognac	Shell	1978-81	312m
Ekofisk 2/4H	Phillips	1980-82	70
Eugene Island 266F	Conoco	1971-74	54
Forties B	BP	1976-81	123
Frigg DP2	Elf	1979-81	102
Fulmar	Shell	1981-82	83
Magnus	BP	1983-86	186
OTS	Exxon	1976-78	20
Valhall QP	Amoco	1982-84	69
W Sole C	BP	1969-71	29
WPI (Bay Marchand)	Socal	1954-58	9
WPII (Timbalier)	Socal	1960-63	31

TABLE II: Magnus Platform Monitoring Database

Routine Records - 40 minutes every 6 hours
- December 1983 - April 1986
- 90% valid records

Continuous Records

Date	Hsig
17/1/84	4.2m
22/1/84	10.7
22/11/84	7.1
27/11/84	9.2
22/1/85	4.8
1/2/85	5.4
2/11/85	10.4
10/1/86	12.6
11/1/86	10.3

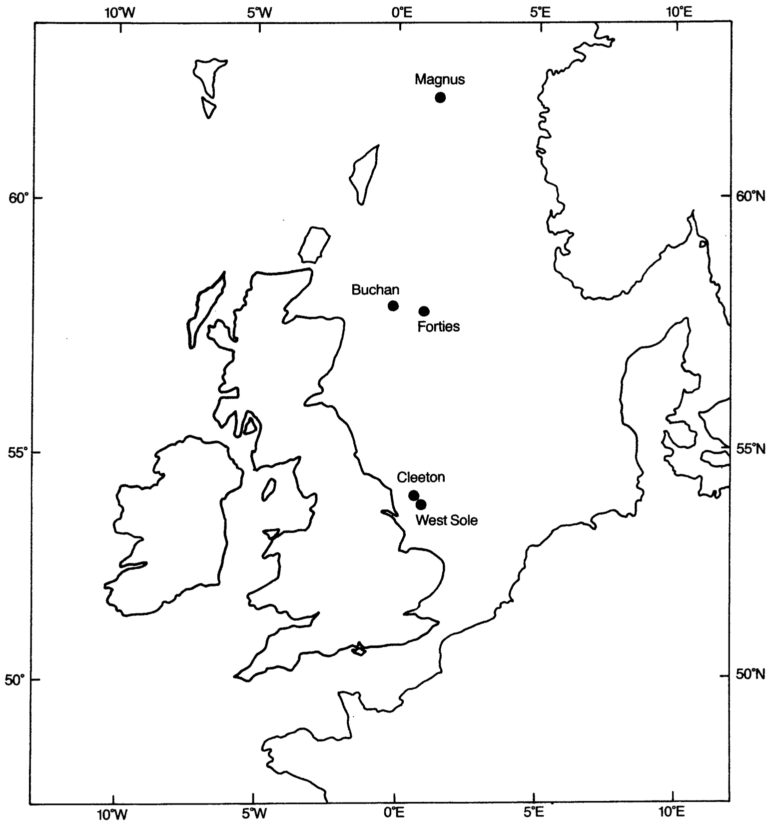

Fig.1. Location of Magnus field

platform was chosen with subsea wells at the field extremities.

In 186m deep water and with with 31,000te topsides weight, Magnus is one of the heaviest steel jackets ever installed; at floatout it weighed 34,000te. It was designed to be self-floating at installation with the main buoyancy being provided by two 10m diameter legs. In operation these large legs are used for storing water and diesel.

The size of the platform and the expected harsh environmental conditions made this structure an ideal candidate for testing how well design predictions conform to reality. It was therefore instrumented for in-service environmental, structural and foundation monitoring.

a) **Environmental Monitoring System**
In accordance with Statutory Instrument 1019 (1976), instrumentation was installed to measure the following parameters: wind speed and direction, water surface elevation, air pressure and temperature, sea temperature.

b) **Foundation Monitoring System**
The foundation monitoring was carried out as a Joint Industry Project with BP managing it on behalf of the nine partners. This was conceived as a research project to measure the behaviour of pile groups.

Instrumentation consisted of strain gauges and accelerometers at the base of one of the main legs and pressure settlement gauges on the piles. Details of the system and results are currently confidential to the participants.

c) **Structural Monitoring System**
The major objective of this system was to verify the satisfactory structural performance of the platform. However, during the course of the measurements it became clear that reality deviates significantly from theory, and it became important to examine the reasons for this.

The structural monitoring instrumentation is illustrated in fig. 2. It consisted of 32 strain gauge assemblies on 8 major load carrying members at -48m and -81m elevations; and 8 accelerometers located at the +24m deck level and at -55m. Wave height and wind direction data from the environmental monitoring system were also recorded. The system was designed to give

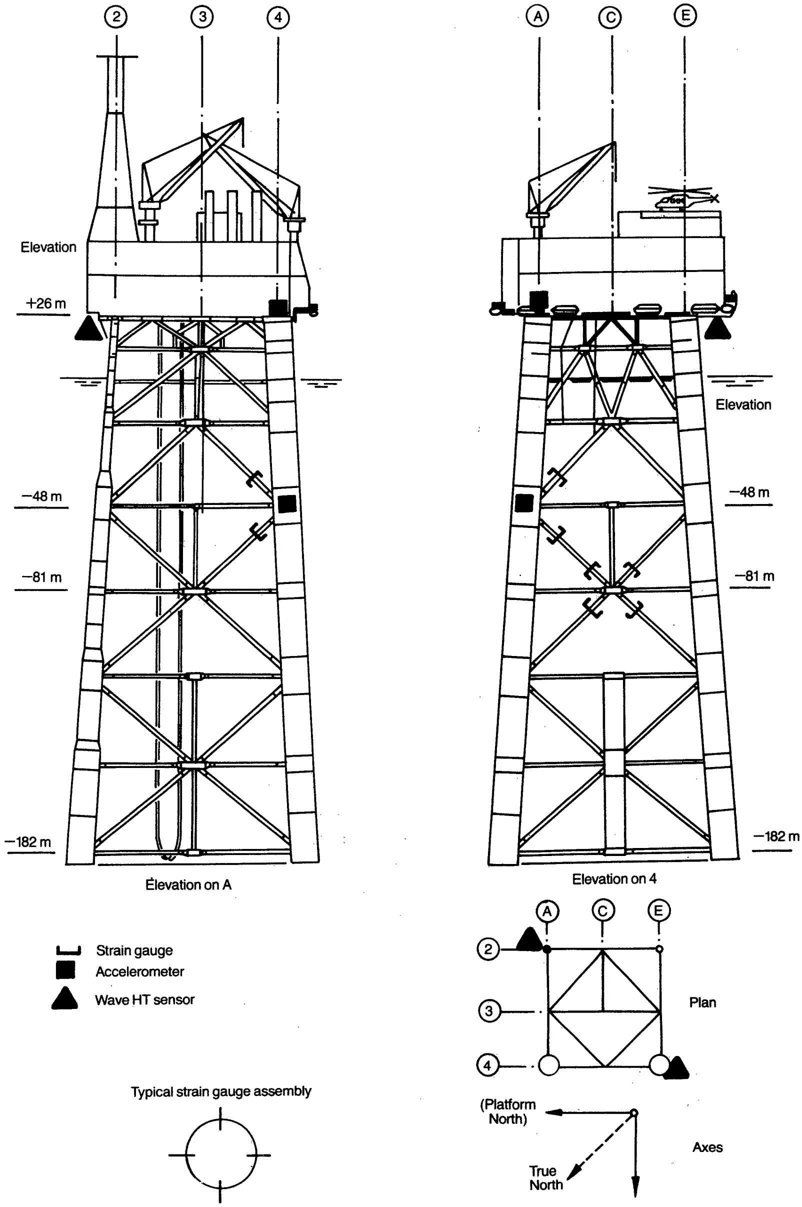

Fig.2. Magnus structural monitoring instrumentation

considerable redundancy in the measurements.

Data collection occurred routinely for 40 minutes every 6 hours, with continuous recording during storms. Raw data was stored on tape offshore, with analysis taking place at a later date onshore.

The system performed well with only three of the strain gauges drifting and one accelerometer failing. During the period from December 1983 to April 1986, approximately 90% of the possible recordings were made and validated. The largest storm encountered was on 10th January 1986 with a significant wave height of 12.6m; the largest individual wave reached 21m.

Routine analysis was carried out on all readings. Deck displacements were obtained by integrating the deck acceleration signals, and general statistical parameters such as mean and standard deviation were calculated for each 40 minute period. The predicted fatigue damage was estimated for each recording by the rainflow counting method. The natural frequencies and mode shapes were also determined. Detailed analysis was carried out on each of 12 selected storm recordings (see Table II). Data was generally found to be of high quality and consistent.

Results

The main results are as follows:

a) The expected maximum 100-year design wave height was reduced by 3m or approximately 10%. This reduction is partly due to improved techniques of oceanographic analysis and to extending the database to include wave records from neighbouring platforms.

b) The platform response is linear with increasing wave height to about 12m (fig 3). With higher waves the response has a non-linear component estimated to be 30% of the total at the design condition. As the strain gauges were located in primary structural members, this implies that the overall platform behaviour is dominated by the inertial component of wave loading.

c) The platform's natural frequencies are about 25% higher than predicted. The structure is therefore less dynamically active than expected; the dynamic amplification at the 100 year design condition is only 35% of that predicted (fig. 4). This is

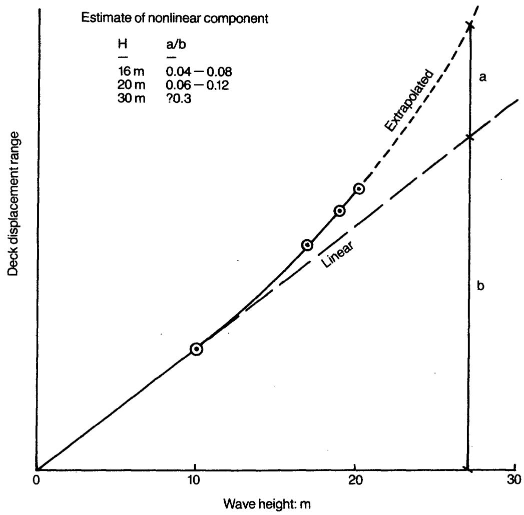

Fig.3. Deck displacement with wave height

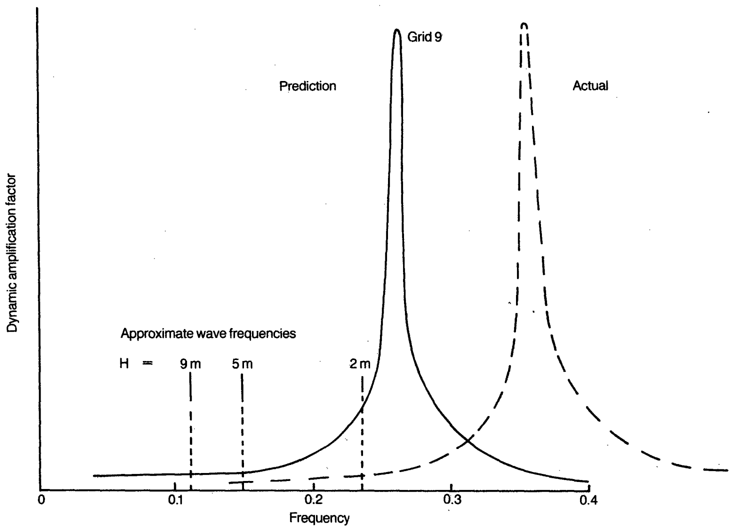

Fig.4. Displacement dynamic amplification factors at elevation +12 m

thought to be mainly because the soil stiffness is greater than that assumed in design.

d) Stresses in the members were considerably overpredicted. At the 100 year design condition the overprediction was estimated to be a factor of 2.5. Together with b) above, this indicates that the Morrison inertia coefficient of 2.0 used in design was too high.

e) The node fatigue lives estimated from measurements were considerably longer than those calculated in design.

A brief summary of published results from other platform instrumentation schemes shows that the Magnus measurements fit in well with them.

Fig. 5 compares the response of four platforms to increasing wave height. The Valhall platform (refs 2,5) had a linear response to a seastate with a significant wave height* of 8m. On primary members on Forties B (ref 4), there was an approximately linear relationship with wave height to about 6m. The Frigg DP2 platform results (ref 9) fit a straight line to a wave height of about 8m as well as they do the curve shown in the paper. Since Magnus has such large diameter main legs, it is to be expected that inertial loading will dominate to a higher seastate than on the other platforms.

Forties, Ekofisk 2/4H (refs 5,8) Valhall and Frigg DP2 are all reported as having higher natural frequencies than expected. In the case of Frigg this was demonstrated to be because the actual soil stiffness was greater than predicted.

On Fulmar (ref 3) the predicted stress ranges on the bracing just below the splash zone are 1.4-3 times that measured. The authors concluded that this is because the inertia component of the loading was overpredicted using an inertia coefficient of 2.0. The measured deck displacements on Frigg DP2, when extrapolated to the 100-year condition, indicated that the extreme displacements would be only 30-60% of those predicted. On the OTS (ref 1), overturning moments and base shear were found to be 10% overpredicted. Predictions of member stresses on the Eugene Island 266F platform (ref 7) were found to be slightly conservative even when currents and marine growth were not included in the model.

On Cognac (ref 6), the measured stress distributions were only 2/3 of that predicted, although the wave height distribution was as expected. The authors concluded that the difference is due to the conservative assumptions of the stress anlaysis. On Fulmar and on Valhall the average stress ranges were about 50% of that predicted from the the measured seastate.

We have therefore been able to establish with some confidence both that the Magnus jacket is subjected to lower than expected environmental conditions and that its response to a given condition is less than expected. Fig 6 shows the effect of revising the design parameters in accordance with the structural monitoring results. The deck displacement at the 100 year design storm has been reduced by 35%. It can be seen that the new prediction is still conservative but the expected overprediction factor is now a more respectable 1.3.

The total cost of establishing these conclusions was £1.3m; most of the cost was in purchasing and installing the hardware. This figure, although large in itself, represents only 0.16% of the total installed cost of the platform.

Since Magnus was commissioned, the field reserves have been upgraded and future development will require drilling of four additional wells. Due to topsides facilities development, Magnus has been limited to 16 platform-drilled wells. Using the environmental and structural monitoring results, we have been able to demonstrate that up to 20 wells may be drilled directly from the platform. The potential savings of this scheme, as opposed to drilling the new wells as subsea satellites, is about £50m or approximately 40 times the cost of the system.

Future Use

The high cost of retrieving data tapes and analysing them onshore, coupled with the fact that advances in microprocessor technology had made the Data Acquisition Unit obsolete, led in 1986/87 to a review of the future of the Magnus monitoring systems.

The environmental monitoring system will continue to collect data over the life of the platform as required.

The foundation monitoring project is now complete and recording has been discontinued. The sensors are still in place however and it would be possible to make

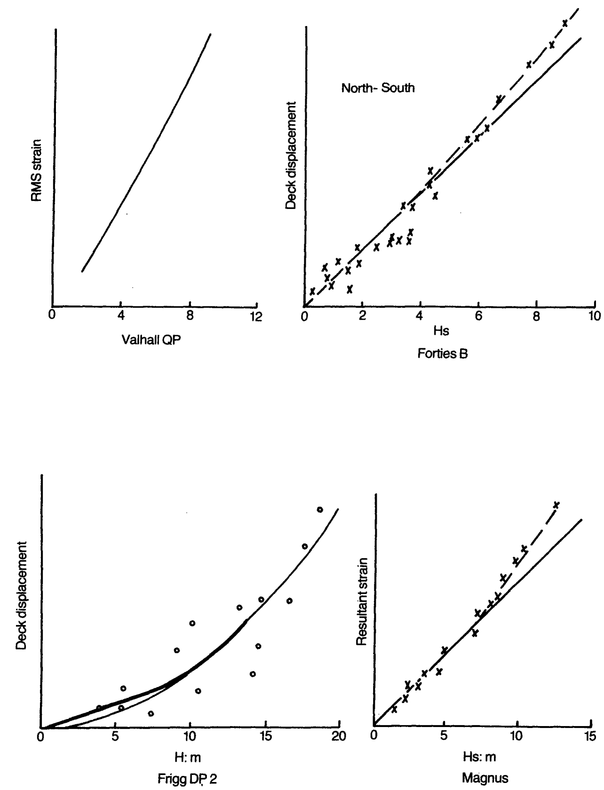

Fig.5. Linear platform behaviour

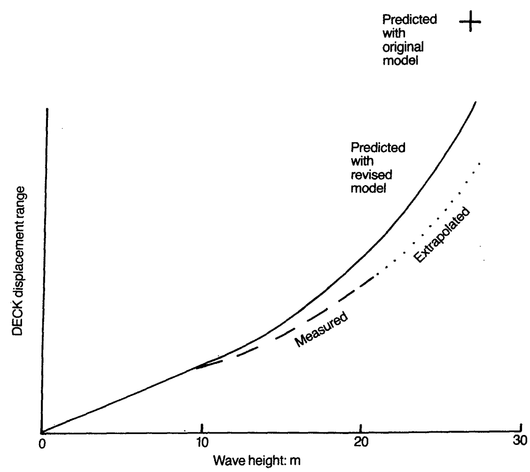

Fig.6. Comparison of measured deck displacements with predictions

further measurements if required.

The structural monitoring system will continue to be used in a rather different way. The Data Acquisition Unit has been replaced by a modern microcomputer capable of collecting and analysing data offshore at a fraction of the cost of the old system. The principal objective now will be to complement the annual subsea inspections by continuously monitoring the overall integrity of the structure - any serious structural damage will be detected by changes in the natural frequencies and mode shapes. Strain data will be collected only in severe storms, to increase our understanding of the platform behaviour in high seastates.

The old problems with platform monitoring have to a large extent been overcome. Instrumentation and data processing are becoming cheaper and more reliable all the time. With real time offshore data processing the platform operators will see some immediate benefit from running the systems. And with increasing confidence in both the raw data and its interpretation, there is every expectation that platform monitoring can continue to be a very valuable tool in reducing whole life field costs.

Acknowledgements

The success of the Magnus Structural Monitoring Project has been due to the efforts of a large number of people, but the contributions of R.M. Webb and D.G.M. Eggar of BP, of M. Birkinshaw, formerly of BP and of M. Kenley of W.A. Fairhurst must be particularly acknowledged. The authors also wish to thank the British Petroleum Company for their permission to publish this paper.

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* Significant wave height (Hsig) is the mean height of the highest third of the waves in a given record. It is a measure of the energy of the seastate. Numerically it is equivalent to four times the standard deviation of the water surface elevation.

8. A cost-conscious approach in offshore structural engineering

W. VISSER, Shell UK Exploration and Production Ltd

SYNOPSIS. Shell Expro (Shell UK Exploration & Production Ltd), operating in the North Sea on behalf of the Shell/Esso joint venture, has interests in the exploration, development and production of oil and gas projects in three main areas of the North Sea. Following the reduction and recent stabilisation in oil prices and the need to bring smaller field into operation a high emphasis is placed on a cost-conscious approach to all disciplines including structural engineering through the build-up of knowledge in all apsects of the work and the incorporation of cost effective ideas in new projects. This paper describes this approach as applied to structural engineering through a number of recent examples.

INTRODUCTION

1. Over the past ten years Shell Expro has had a continuous development programme of platforms in the UK sector of the North Sea.

1978 - 1982 North Cormorant and Fulmar
1982 - 1986 Sean Development (3 platforms)
1984 - 1987 Leman F & G
1984 - 1988 Tern & Eider
1986 - 1989 Kittiwake

As far as possible the lessons learned in the past are applied to the next development. This paper covers various aspects in design and fabrication of topsides and substructures while in the latter part of the paper some important research issues on environmental loading and fatigue are discussed which could have a major bearing on future trends in the subject area.
Current thinking in Shell Expro is significantly influenced by the success of applying cost saving ideas to the Kittiwake platform development. This platform can be seen as the first of a family of lift installed structures. In addition various ideas from Tern and Eider projects (ref. 1, 2) are now

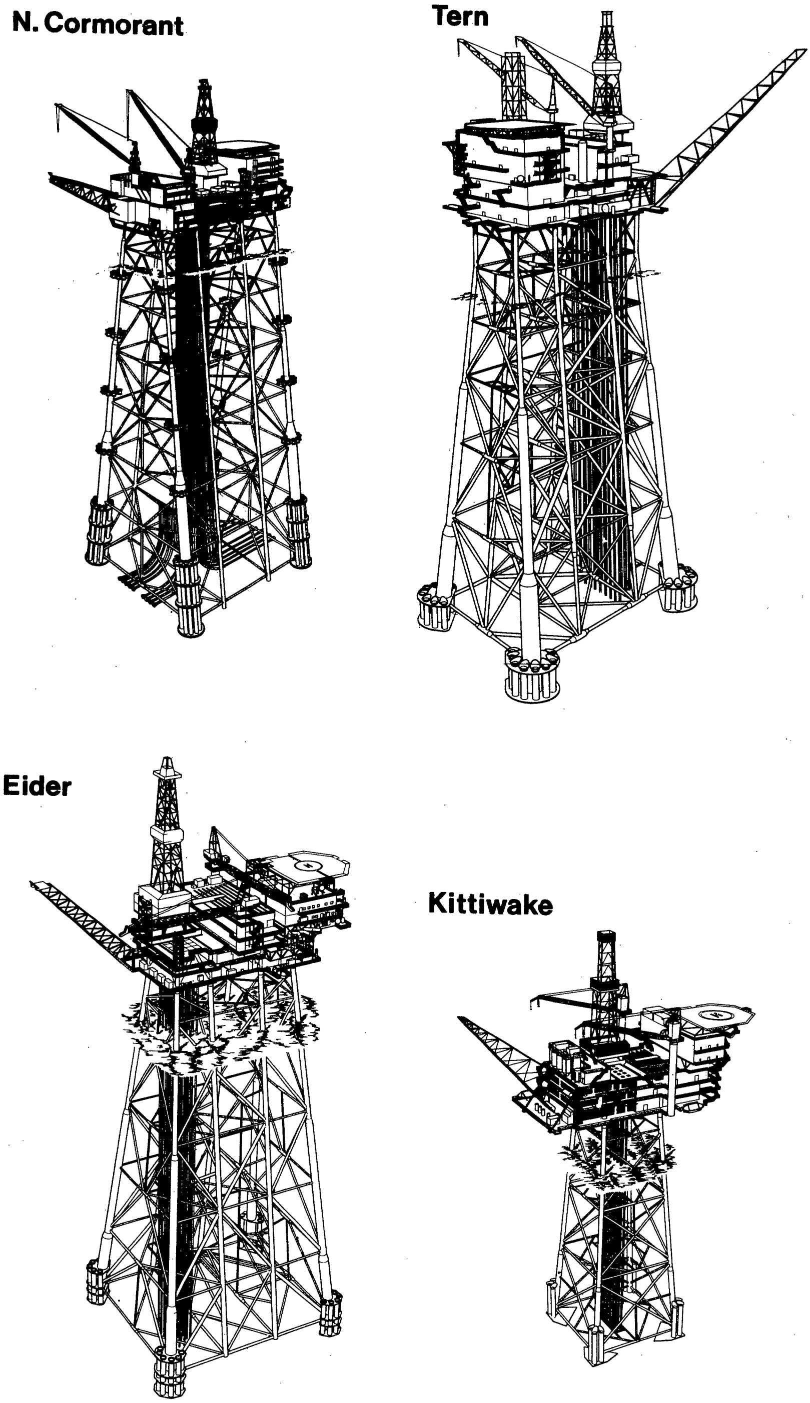

Fig.1. Four of the platforms developed by Shell Expro

becoming common practice such as vertical piles, reduced number of bays and simplified geometry for ease of fabrication. Also the use of a large integrated deck as applied to Kittiwake has been made possible by the availability of the large SSCV's.

THE DESIGN AND FABRICATION ENVIRONMENT

The Engineers

2. Over the past ten years Shell Expro has had a continuous development programme of platforms in the UK sector of the North Sea. This has an immediate benefit in that lessons learned on one project can easily be applied in the next. This is partly ensured by letting engineers first become familiar with Shell Expro's practices and project problems in a Central Engineering environment; while at the same time the most important development issues are collected in ERD's (Engineering Ref. Documents). Thereafter the engineers are made responsible for the structural engineering work in a project team; the good contacts established earlier facilitate the continuous flow of expertise and the incorporation of new ideas into a project.

The position of structural engineer in a project team is highly desired by the engineers because it has clear objectives and boundaries, it covers a large area of structural engineering principles, provides independent operation and well balanced responsibilities. The working method employed by Shell Expro to control the many activities of the design contractor through the use of a CTR (cost-time-resource) catalogue of activities is now well established and facilitates the task of the engineer, allowing him to concentrate on major technical issues.

Fabrication

3. The success of a cost effective design hinges very much on the fabrication costs and from past experience this seems to be as much governed by market forces as by excellence of the design. The responsibility of the designer also becomes apparent when the consequences of poor design are considered since a fabricator is not at a competitive disadvantage when a poor design is offered for quotation. In establishing the ground rules for the design it is essential that the requirements of all fabricators who are likely to be selected to participate in the bidding are incorporated. This is a conflict in itself and its consequences can only be minimised by stimulating the successful contractor to submit further cost effective ideas after the award of contract.

Over the past few years the exchange of information between the designers and fabricators has definitely improved. However, except for easily identifiable items such as welder qualification, plate testing and inspection, it seems to be difficult to provide an accurate cost breakdown of the fabrication process.

To progress cost reduction in the short term, Shell Expro hopes to see that certain practices as employed by fabricators in the Gulf of Mexico can be made acceptable to the North Sea because there is still a significant fabrication cost difference between these two geographical areas. For example, the massive Bullwinkle platform is assembled from tubulars as a Meccano set: all tubulars cut and bevelled to fit in place leading to a fabrication cost per ton (even before the recent dollar exchange rate movement) well below the Tern and Eider figures.

Materials and Welding

4. This is a vast subject in itself but in the context of this paper a few observations can be made.
Over the past five years a massive amount of data has been gathered in the welding of St.50 and with confidence this material can be applied to both substructures and the main truss of the topsides.
For the topsides (much more than for the substructure) weight savings can be identified in the use of higher strength steels and Shell Expro gathered sufficient evidence that, except for the distortion of thin plates, the welding of these materials will not be more difficult than normal steels. However, as yet it has not been possible to obtain assurance that the consequence of thinner wall thickness as a result of the higher strength will lead to direct fabrication cost savings. Therefore Shell Expro's position is to promotet the use of higher strength steels only when other, indirect cost savings (as a result of weight limitations) can be identified.

Thet third observation is on CTOD. History shows that the full application of CTOD is a cost and time consuming business but some cost savings can also be identified. For example, CTOD is a powerful quality assurance tool: the absence of any welding related problems during the Tern and Eider fabrication can be attributed to proper material and welding specifications which were established using CTOD.
As a separate issue, in the author's opinion, the application of PD6493 (ref. 3) to areas of high strain gradients (as compared to uniform stress) in a fitness for purpose approach is questionable. A further cost saving can be identified in the possible reduction of PWHT (post weld heat treatment). From a fatigue point of view there is no evidence that PWHT has any advantage (ref. 4), while our current data base on St.50 seem to indicate that there is little objection against reducing PWHT in most nodal joint fabrication.

TOPSIDES

5. From an outsiders point of view the main difference

between old and new topsides design is in its mere size: the introduction of HLSSCV (heavy lift semi-submersible crane vessels) makes it possible to increase modules from 2000 to well over 7000t lift weight and to bring integrated topsides within the grasp of present lift vessels.

Design methods

6. The design methods have not changed significantly: in general the API/AISC code is applied which provides a proven, but conservative, design tool. Recently with the introduction of BS5950 based on LRFD (load-resistance-factor-design) it is posible to incorporate beam strength more realistically since a certain amount of secondary bending has no real effect on axial strength of stocky members as used in topsides. This is properly assessed in BS5950 and therefore some 10% weight reduction can be obtained by applying this code. Subsequently, LRFD method can be applied at full structure level rather than at element level thereby making better use of the load shedding potential in a statically redundant structure. The first pilot studies indicate significant potential cost savings of some 20% and therefore additional work will be carried out to demonstrate how these non-linear analysis methods can best be incorporated into design. One load case which immediately comes to mind for relaxation when using LRFD methods is the special load case of uneven support point position, the consequences of which are probably severely over-estimated using API-AISC.

Global and Local Design

7. Items to be considered in global design are the use of fabricated beams or tubulars and stress skin versus trusses. Since the introduction of open modules it is clear that stressed skin can only be seen for living quarters (LQ) and separate (closed) modules. However, the design of LQ's is a subject in its own right and will not be addressed in this paper. The selection of beams or tubulars is really governed by cost only: tubulars are technically more effective, have smaller wall thicknesses and may well lead to smaller transverse beams; on the other hand beams are heavier but can more cheaply be fabricated provided wall thicknesses are not excessive. Therefore the final choice is based on wallthickness and on acceptance of a weight penalty.

The detail design of module beam joints has received much attention but, despite discussions with fabricators, and provided that basic design principles are adhered to, it seems to be a prime area for preferential engineering.
If a joint in a module is really complex then a cast steel solution could be considered as well but the marginal cost advantage together with the scheduling constraint rarely favour this solution. An exception should be made for lifting padears and support points: in these areas castings

are very cost effective and offer scheduling advantage during fabrication. Cast padears can be designed flush at the top; therefore they can be left in place and re-used for abandonment thus offering additional savings.

Lifting of large modules

8. The critical phases of a heavy lift are in the take-off and landing. In these phases the maximum sling loads and the largest impact forces are experienced. Recognising this design problem Shell International was instrumental in developing computer software to simulate and carry out time domain analyses of the heavy tandem lift operation under a random wave environment. This software was used for the Eider and the Kittiwake integrated deck design.

Weights

9. Unforeseen topsides weight growth has been a problem in many projects. Therefore, some years ago, Shell Expro critically reviewed this subject and its recommendations are laid down in an ERD (Eng. Ref. Doc.). From this review it appears that the weight growth during the various stages of a project (conceptual design, detail design, fabrication, commmissioning, post-completion), expressed as a percentage of the total weight, follows a certain, identifiable pattern; the ERD then specifies which percentage of weight growth to use during these various stages of a project (e.g. 25% weight growth between the completion of the feasibility phase and the as installed weight of a module). However, Project Managers can employ lower percentages if the proposed facilities are well established or if potential areas of weight savings can be identified. After the completion of each project the accuracy of the weight growth percentages are critically reviewed.

The advantage of the procedure is that weight growth can be managed and will not seriously affect the project schedule. It also puts weight consciousness where it should be i.e. at the early phases of the project.

Additional design cycle

10. Because of the large uncertainty in weights and weight distribution there is, from a structural engineering point of view, a preference to add an additional design cycle after the positions and weights of the major components have been established. However, in most cases, the topside structural steel is on the critical path because the steel drawings should be completed for fabrication during the early phase of the detailed design of the topside facilities. Therefore there may be a conflict between the economics of the steel deck and that of the total project which requires early awareness.

STEEL SUBSTRUCTURE

Design consideration

11. Recent developments in steel substructures aim at simplicity. The introduction of HLSSCV has meant a significant change here: three years ago a simple lift installed riser jacket in the Brent area (140m waterdepth) would just have been feasible whereas now drilling or production platforms in waterdepths up to 200m are within our reach. Launched jackets are indeed neither simple nor cheap: some 25% weight is added to slide a design load of the order of weight of the platform over about half its length. If we compare that with lift installed platforms where over 90% of its weight is governed by the as-installed condition then the cost advantages are immediately apparent.

Both Tern and Eider also highlight how better understanding of design loading can led to significant cost saving. Through a better understanding of vortex shedding behaviour in a random wave and current environment (ref. 5) it was possible to reduce conductor diameter from 30" to 26" and to increase the bay height, thus reducing the number of bays in Tern and Eider as compared with North Cormorant by one bay. Both these changes have a direct impact on the total design environmental loading but also significant secondary cost saving can be allocated to them.

Further considerations on lift installed jackets

12. When considering the possibility of lift-installing a jacket in 200m water then (because of lift weight restrictions) limitations should be imposed on the combination of topsides weight and number of conductors and risers. By separating the topsides it can well be envisaged that a full development consists of two platforms: a drilling platform and a production platform. Thus in future Northern North Sea developments may well resemble field developments of the Southern North Sea. On the other hand, the load carrying capacity of lift installed jackets for the Central North Sea appears to be adequate to carry both topsides and conductors.

Further enhancement in platform load-carrying capacity may be feasible by installing a substructure using three cranes of two HLSSCV. Such a three point lift guarantees a necessary statically determinate lifting arrangement although additional difficulties may occur establishing an upending strategy.

Lift installed, deepwater jackets will suffer from their lack of stability during the unpiled phase of the platform installation. This requires careful attention, because the solution as sometimes used in the South China Sea of tying a light jacket to its installation barge cannot be applied unmodified to North Sea conditions.

Foundations

13. If simplicity is a means towards cost effective platforms

then the recent developments in foundation design should definitely be mentioned. Following a careful review of reliability in underwater pile driving both the Tern and Eider teams could proceed with using vertical piles for their platforms. The direct benefits in reduced fabrication of the pile guides and the indirect savings from reduction in wave loading are significant. The larger pile diameter of 2134mm means that wall thicknesses at mudline are not excessive; therefore an interesting balance is obtained that all foundation criteria (pile drivability, axial and lateral capacity) can be met at the same time.

Extensive site investigation significantly reduces any uncertainties in soil conditions, while the critical review of design equations plus participation in joint industry projects (e.g. BP pile test programme) and initiation of studies (piles in sand) ensures optimal design of the piles. A comment should here be made on the common practice in foundation engineering to use upper bound figures for pile drivability analysis and lower bound values for pile capacity assessment. A conclusion of this practice is that the more soil tests we take for a platform foundation assessment the more conservative one becomes; this paradox has not yet been resolved. An exception can, however, be made if we take a single borehole per pile group and do a borehole specific, pile group dependent design and evaluation of drivability and capacity: this approach is considered more cost-effective.

Southern North Sea aspects

14. The Southern North Sea is an area which offers the greatest potential for different concepts, e.g. a large variety in proposals is offered for wellhead protection jackets for 1 or 2 wells. A detailed cost study incorporating all aspects from design to fabrication, installation and commissioning should give guidance on the most attractive solution. When the number of wells is large or for high topside loads the conventional jacket evolves into a pile guide frame with some intermediate bracing; this is particularly apparent when vertical piles are used which makes the pile driving easier and facilitates installation of topsides.

The difficulty in designing a platform in a new area in the Southern North Sea is, surprisingly, the lack of environmental data. Because of the complex bathymetry the design wave and current data are truely site specific; for example the high current values at the Sole Pit site have a significant bearing on jacket and foundation design. This problem of lack of data can be overcome to a large extent by recording of waves and currents simultaneously in a new site and in a nearby fully tested area. Uncertainty in this matter will automatically result in additional platform costs. An additional problem was encountered in the design of the Leman G (ref. 6) and some other shallow water platforms. When the water depth is less than 20m the possibility of breaking waves cannot and should not be disregarded. Contrary to common belief breakers have a positive effect in that maximum wave loading is reduced. This was confirmed in tests sponsored by Shell Expro at Herriot Watt University: not only did these tests establish a new, lower value of Hmax/WD (max. wave height over waterdepth) than currently recommended in the Guidance Notes; also, wave particle velocity measurements show that higher order Dean stream functions adequately describe the model test results. This conclusion of lower H_{max}/WD was also observed in random wave tests in shallow water. These findings are essential for developing a cost effective jacket structure for shallow water.

Push-over analysis of platforms

15. In order to obtain a better understanding of the actual shear carrying capacity of jacket structures it is possible to carry out non-linear, "push-over" analysis. Through such exercises a good feel for strengths and weaknesses of designs based on the API code can be obtained. For example, an individual low pile capacity can be considered acceptable if sufficient reserve strength is available in the remainder of the foundation and if the jacket allows redistribution of foundation loads. Other failure mode analyses showed the weakness of K bracing over X bracing from a reserve strength point of view and this insight can fruitfully been used in design of new platforms (e.g. Kittiwake has an X bracing pattern). So far, in-house calculations confirm consistency between the checking of a substructure using API's working stress method or a DnV type limit state verification.

RECENT RESEARCH & DEVELOPMENT

Wind, wave & current

16. The most surprising element in the jacket design process is the selection of the important fluid force drag coefficient (C_D). During the early seventies the selection of C_D = 0.5 was based on laboratory tests on perfectly smooth surfaces. Realising that marine growth is important C_D was gradually increased first to 0.6 then to 0.7 which is still well below the value measured in a laboratory environenment on roughened cylinders of 1.0-1.2. This controversy remains unchanged when reviewing the paucity of worldwide platform collapse events. This difference can only be justified when assuming that other, conservative aspects, such as random, short-crested seas, would compensate for the observed discrepancy. Recently a series of exercises was completed giving full support for design environmental loading based on C_D = 0.7 using actually measured data for C_D. This in itself is a subject for a one-day seminar. The contributions leading to this

understanding came from Shell and Exxon in the following way;

(1) OTS structure - confirmation of actual C_D (Exxon)(ref.7)
(2) Gotenburg tests - confirmation of C_D on large scale models in oscillatory flow (Shell Oil) (ref. 8)
(3) Wave stretching - development of model for (horizontal) wave particle velocity above MSL (Shell Oil)
(4) Realistic software - software was developed to analyse realistically random, short-crested waves in the time domain (Shell Oil, Shell International, KSEPL)

Application of this software to a computer model of North Cormorant under a realistic wave and current climate revealed a close correspondence between the total loading obtained with this software and the design loading obtained with the design wave approach using a C_D of 0.7. A very encouraging result!

Coherence of wind, wave and current

17. Another souce of discrepancy between design loading and actual platform loading is found in the coherence of design wind, wave and current. The design guidance on this matter lacks uniqueness while significant reductions can be expected when the design wave is to meet with realistic, simultaneous wind and current. This is one of the main objectives of the NESS (North European Storm Study) international joint industry project. The software mentioned under 16. can then be used (a) to validate reduction in loading and subsequently (b) to make adaptions in the design wave model.

Tern platform instrumentation

18. In order to verify the above conclusions the Tern platform has been fully instrumented with the principal objective to measure the total base shear and overturning moment during more severe environmental conditions. Therefore within a few years Shell Expro will have the information to justify a more realistic and probably, significantly lower loading which will have a beneficial effect on development of marginal fields.

UKOSRP and fatigue

19. In the design of steel jacket structures much attention has to be paid to fatigue aspects. Shell Expro participated in UKORSP - which stands for UK Offshore Steel Research Project. The additional data confirmed the earlier, more speculative recommendations and will give more confidence in the fatigue design of our platforms.
From a critical review of the UKOSRP data it could, however, be concluded that the fatigue SN curves as presented in the Dept. of Energy Guidance Notes are non-conservative. A review of the careful procedure to arrive at these SN curves has not revealed a flaw in the argument.

Actual observations on fatigue

20. Shell Expro has resisted the above trend and the arguments are twofold. First, fatigue of platforms is governed to a large extent by fluid inertial loading. The magnitude of this loading is, among other things, linearly related to the added mass coefficient C_M for which a value $C_M = 2.0$ is not uncommonly used. However, from the Fulmar-A measuring programme (ref. 9) and supported by other research, it appears that C_M in osciallatory flow (a wave) is better approximated by a value $C_M = 1.4$; incorporation of this low value of C_M would increase fatigue lives by approx. 4. Thus, the effect of a possibly non-conservative SN curve as mentioned under 19. is compensated for by a known conservative estimate of the fatigue loading.
This conclusion is supported by inspection evidence on Auk-A and Brent-A. These platforms have been in service for more than 10 years. If new fatigue analysis procedures are applied to these first generation steel structures then many joints would have fatigue lives less than the actual as-installed platform life. From the definition of fatigue life (95% probability of having no through-thickness cracks) together with other information on fatigue crack growth some of the joints should have failed and many should have significant crack-initiation. With no more than a handful of exceptions this is not the case.

Steel castings

21. For some years manufacturers such as River Don Foundry (UK) have encouraged the application of steel castings in the offshore industry. In general castings have a freedom of shape which can never be met by their welded equivalents but the disadvantage was in the paucity of data to support design. In order to investigate the mechanical behaviour of cast steel the data made available by the foundries was complemented by research data established through a series of small research programmes. In this way particular problem areas could be investigated on an individual basis. Subsequently, Shell Expro was satisfied with

(a) the performance of castings in non-fatigue sensitive areas
(b) the adequacy of ndt inspection techniques and recently
(c) the acceptance of castings in fatigue sensitive areas also for large wall thickness.

As a company we now have substantial experience in the use of castings; the most economic application is definitely found in lifting padears for topside modules and integrated decks.

Tubular joints

22. Over the years Shell Expro has stimulated research activities in the field of tubular joints. For unstiffened

joints the in-house program PBM-Shell and the extensive results reported by Efthymiou at the 1985 BOSS conference (ref. 10) on stress concentration factors should be mentioned. This work gave further support to the use of well established equations within their relatively small range of application, but, more importantly, extended the understanding for much broader classes of joints.
In the same field the joint-industry project by Lloyd's Register is establishing SCF's for complex (stiffened, overlapping, multiplanar) tubular joints should be mentioned which provides invaluable data for the design and re-analysis of platforms. The recent completion of the background document to the new DEn draft guidance notes on ultimate capacity of tubular joints is helpful in that it supports the design of optimally designed joints at a uniform level of safety which should therefore be the most cost-effective solution.

CONCLUDING REMARK

23. Through the critical review of all aspects in the structural design of topsides and substructures and through sponsoring and support of research Shell Expro remains determined to seek further cost-effective approaches in structural engineering.
Over the past few years we have seen a marked change in platform concepts. This paper deals exclusively with the cost effective development issues in steel platforms, but, recently there has been a renewed interest in concrete platforms for Southern North Sea application and this revival may well go North to the deeper waters. All these changes and developments indicate that by better insight further cost reduction in platform developments can be obtained.

Acknowlegement

24. I wish to thank the management of Shell UK Exploration and Production Ltd. for giving me permission to present this paper at this conference.
The paper contains many parts in which the Shell Expro structural engineers in Central Engineering, the projects and in operations have made substantial contributions. Without these efforts the writing of this paper could not have been possible.

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10. Subsea separation as an alternative to multi-phase flow

J. L. CHASSEROT, BSc, Goodfellow Associates Ltd

SYNOPSIS

The need to transport oil and gas over long horizontal distances can be achieved by separation subsea and boosting through separate phase pipes, ideally with partially stabilized oil direct to an export line. The GA-SP project offers innovative technical solutions to solve the problems raised, with a prototype test programme for both individual components and the whole system planned for 1988 and 1990.

THE OPTIONS

1. The problem of transporting well fluids from satellite fields back to an existing platform located 30 to 50 km distant can be approached in a number of ways. Figure 1 shows two options and figure 2 shows two further possible solutions.

2. Subsea separation and boosting of the single phases is a significant option. It offers a method of producing small reservoirs economically (option C).

3. There is a real advantage if partially stabilized oil can be exported directly to a trunk line. (see figure 3.)

CURRENT RESEARCH

4. Several companies including my own, are doing or have done research in this field.

   (a) Separators were tested subsea, probably on the first occasion, 17 years ago in the Zakum Subsea project sponsored by BP and Total.

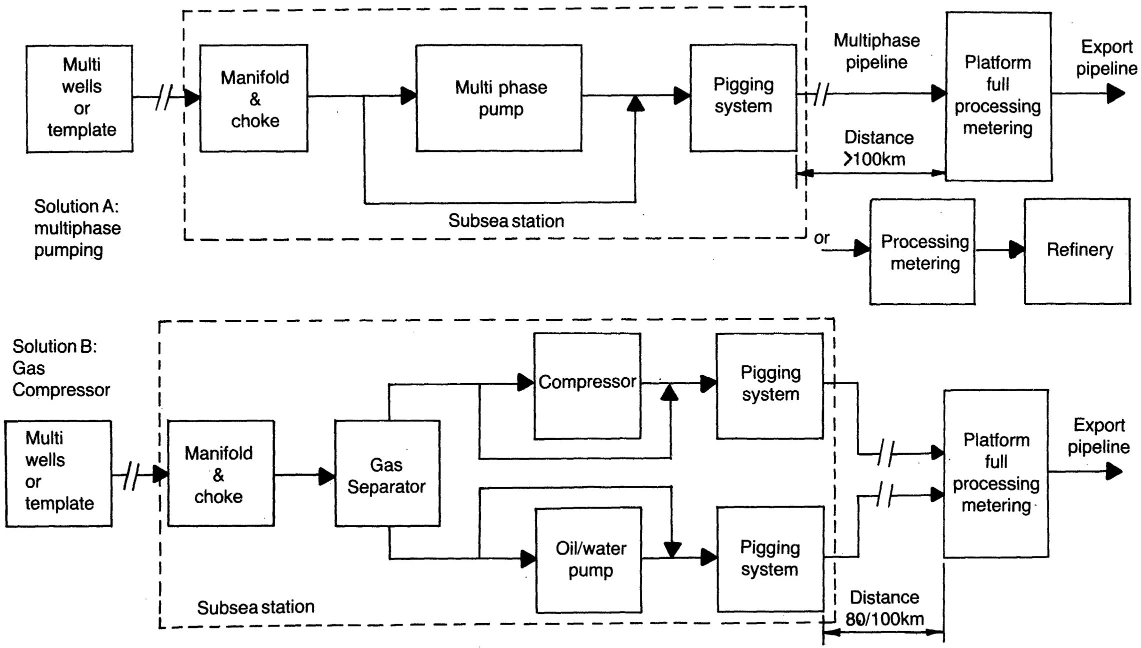


Fig.1. Options of well fluid transfer (subsea) - oil production only - solutions A & B

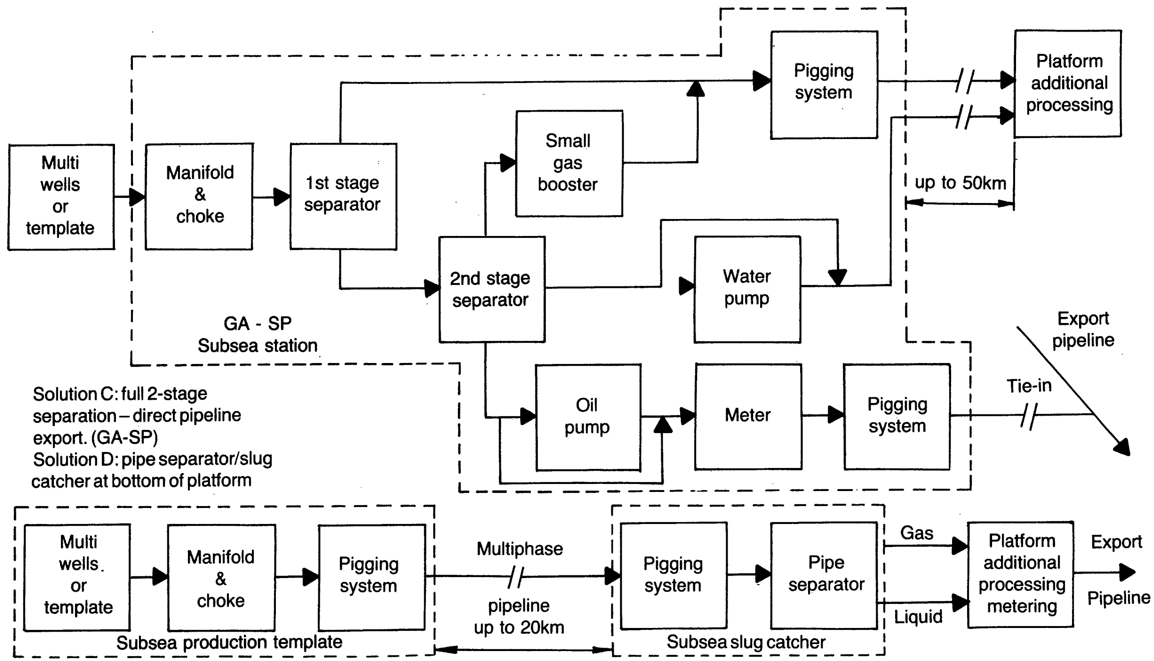


Fig.2. Options of well fluid transfer (subsea) - oil production only - solutions C & D

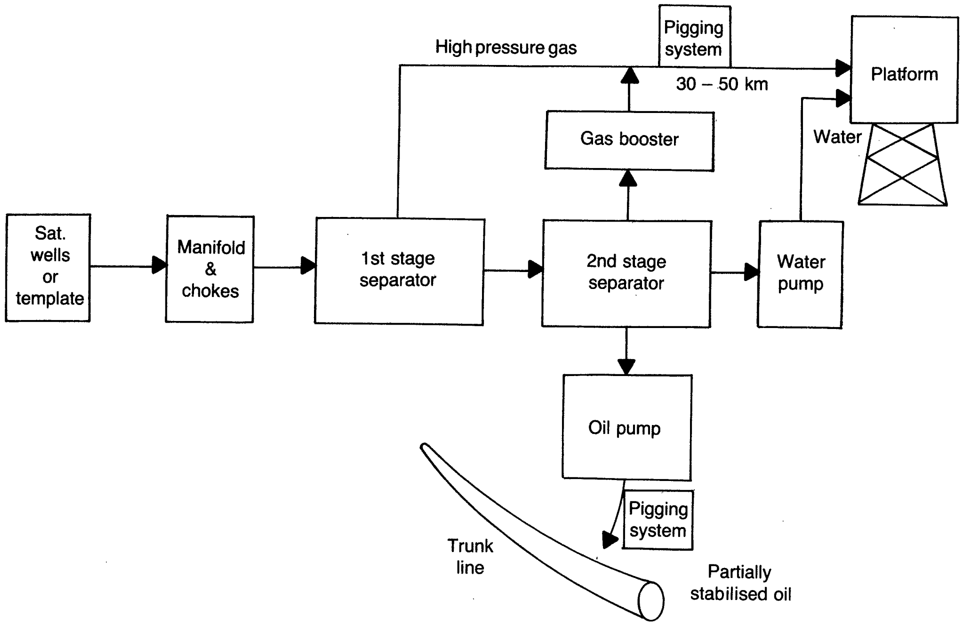


Fig.3. Delivery of partially stabilised oil to trunk line

(b) Kvaerner, we understand, are at an early conceptual stage with a subsea station incorporating single stage vertical gas separators, an oil-water booster pump and a gas compressor.

(c) Texaco's Highlander slug catcher is a tubular subsea separator for gas.

(d) Hamilton, we understand, are working on a subsea separator in conjunction with BOET.

(e) Statoil has ambitious future projects which are expected to incorporate subsea separators.

SUBSEA SEPARATION

5. The GA-SP (Goodfellow Associates Subsea Processing) project is currently being sponsored by the EEC Hydrocarbons Development Fund and by seven oil companies (AGIP, Elf, Chevron, Norsk Hydro, Phillips, Statoil and Texaco). It is interesting to note that a majority of these companies are also funding multi-phase pumping development projects (eg. "Poseidon" or Weirs).

6. The four basic objectives of the GA-SP project are:

(a) Development of a 30,000 b/d seabed processing unit which could operate in water from 150 - 300m, at a distance of up to 30 km (possible 50km) from field centre and existing platform or below a simplified, low cost, low manning, floating control platform.

(b) Application and proving of subsea multiphase flow metering devices and single phase subsea fiscal metering/sampling devices, combined with pigging facilities.

(c) Modularisation of subsea components and support structure for diverless, single datum deployment and connection.

(d) Reliability/failure mode analysis of subsea components and systems.

7. The project started in October 1986 and is planned in three phases:

(a) Preliminary design.

(b) Detailed design.

(c) Construction and Prototype testing.

8. A base case oil scenario was agreed with the participants. The outline basis of design is shown in figure 4. The proposed field lay out is shown in figure 5.

INOVATION

9. Several important aspects of the GA-SP project involve technological development. These include:

(a) ROV retrievable subsea chokes and control pods.

(b) Subsea multiphase flow meters for reservior testing and control.

(c) First and second stage subsea separators.

(d) Single phase pumps for oil and water operating subsea.

(e) Fiscal single phase subsea meter.

(f) Gas boosting and co-mingling.

(g) Subsea Control systems using a master/slave approach.

MODULARISATION

10. Each individual element of the total system and the associated supporting structure wil be modularised to permit diverless, guidelineless, vertical installation, using single datum connection. Various modularisation options were considered taking account of size, manufacturing ease, installation, mating and mechanisation of connections. Other considerations included protection of the system, acess by ROV's and emphasis on minimal support vessel requirement using medium size to large DSV's on the market.

FIGURE 4

GA–SP SYSTEM DESIGN OIL SCENARIO

OUTLINE BASIS OF DESIGN

PARAMETERS	BASE CASE DESIGN	RANGE
Fluid production rate per production well (B/D	7500	5000–1500
Total field fluid production rate (B/D	30000	10000–30000
GOR (SCF/BBL)	500	300–1000
Flowing wellhead temperature (°C)	80	60–100
Gravity of crude (API)	40	30–45
Water oil ratio (%)	5–80	5–80
Flowing wellhead pressure (psi)	800	400–1000
Pipeline lagging	Line trenched	None to fully lagged
Length of oil export line and distance between SPS & platform	30 km	10–50 km
Oil Export Pressure (psi)	15000	500–3000
Water Depth (metres)	3000	150–400
Field Life (years)	10	7–15

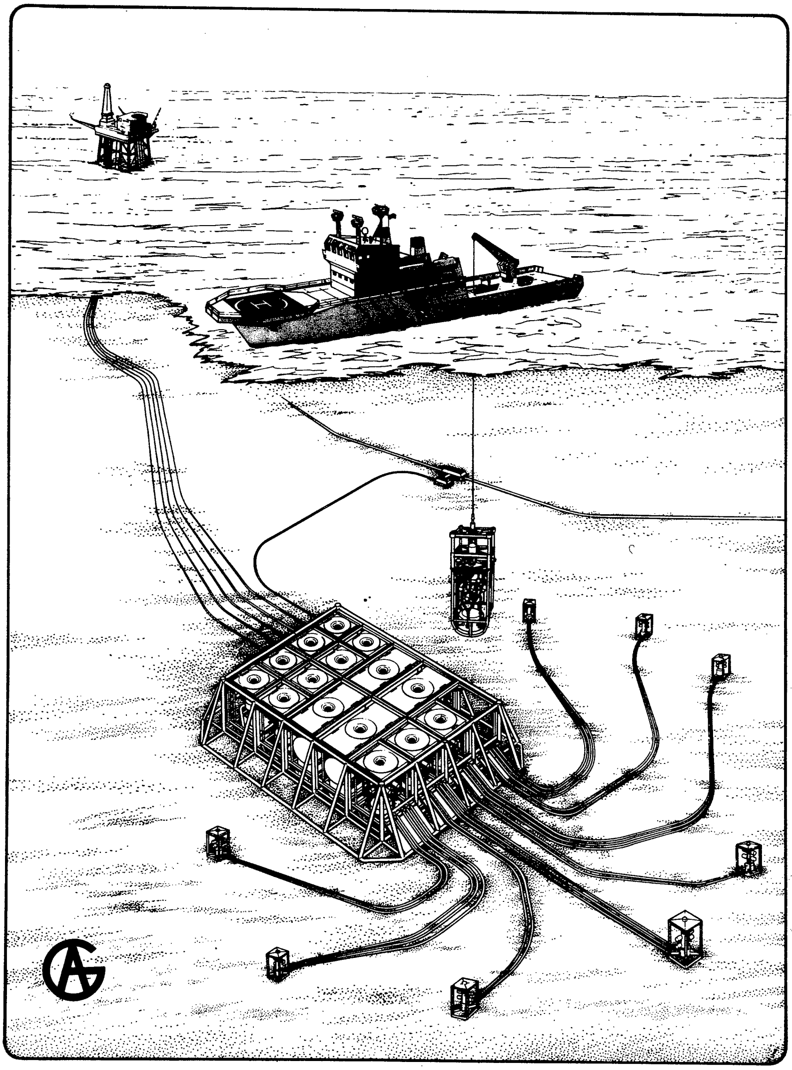


Fig.5. GA-SP system design oil scenario: proposal field layout

11. Components which may need maintenance are retrievable and are in the primary modules. Secondary modules are basically piping serving the various components which should require no maintenance, but none-the-less can be retrieved if necessary. Figure 6 shows an exploded view of the modularised system.

PROGRESS

12. Phase one is now complete and the results are extremely encouraging. Phase two is in hand and progressing to plan. Phase three is scheduled to commence in early 1989 and will involve a dry-dock for dry/wet testing of a prototype system (see figure 7).

RELIABILITY ANALYSIS

13. Data is being collected from a large number of offshore operators on reliability and failure modes of subsea components and equipment. The analysis and conclusions will be made available to the project participants and to operators who supply significant data.

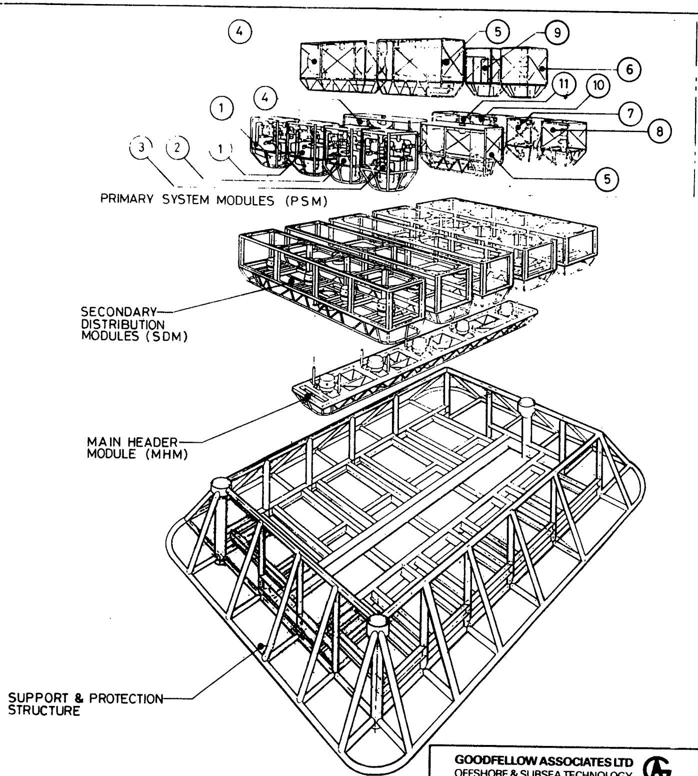
COSTS

14. Capital expenditure estimates have been made (see figure 8) Operating Costs should be no greater that those of existing subsea systems, but with relatively higher energy consumption of which plenty is usually available on existing platforms.

CONCLUSION

15. The GA-SP project offers a practical solution to the problem of developing small reservoirs to ensure low costs and reliable performance during operations.

16. We, subsea engineers are pleased to help the industry develop new alternative technologies particularly if these open the door to more marginal and small fields developments.



3.2(1)

PRIMARY SYSTEM MODULES (PSM)

ITEM	DESCRIPTION	QTY
1	CHOKE MANIFOLD MODULE - PRODUCTION	2
2	WATER INJECTION MANIFOLD MODULE	1
3	MULTIPHASE METERING MODULE	1
4	1st STAGE SEPARATOR MODULE	2
5	2nd STAGE SEPARATOR MODULE	2
6	GAS BOOSTER & PIGGING MODULE	1
7	OIL BOOSTER PUMP (SINGLE PHASE)	2
8	OIL EXPORT & PIGGING MODULE	1
9	FISCAL METERING MODULE	1
10	PRODUCED WATER BOOSTER PUMP	2
11	ELECTRICAL / HYDRAULIC POWER PACK MODULE	1
	TOTAL PSMS	16

GOODFELLOW ASSOCIATES LTD
OFFSHORE & SUBSEA TECHNOLOGY
London 01 821 1377 © GA LTD 19 Aberdeen 0224 643265

Client

Drawn LEC	Date 1/88	Project GA-SP
Checked	Date	Title EXPLODED PICTORIAL VIEW OF GA-SP MODULARISED SUBSEA PRODUCTION SYSTEM
Approved	Date	Drawing No / Rev
Scale		

Fig.6. View of modularised system

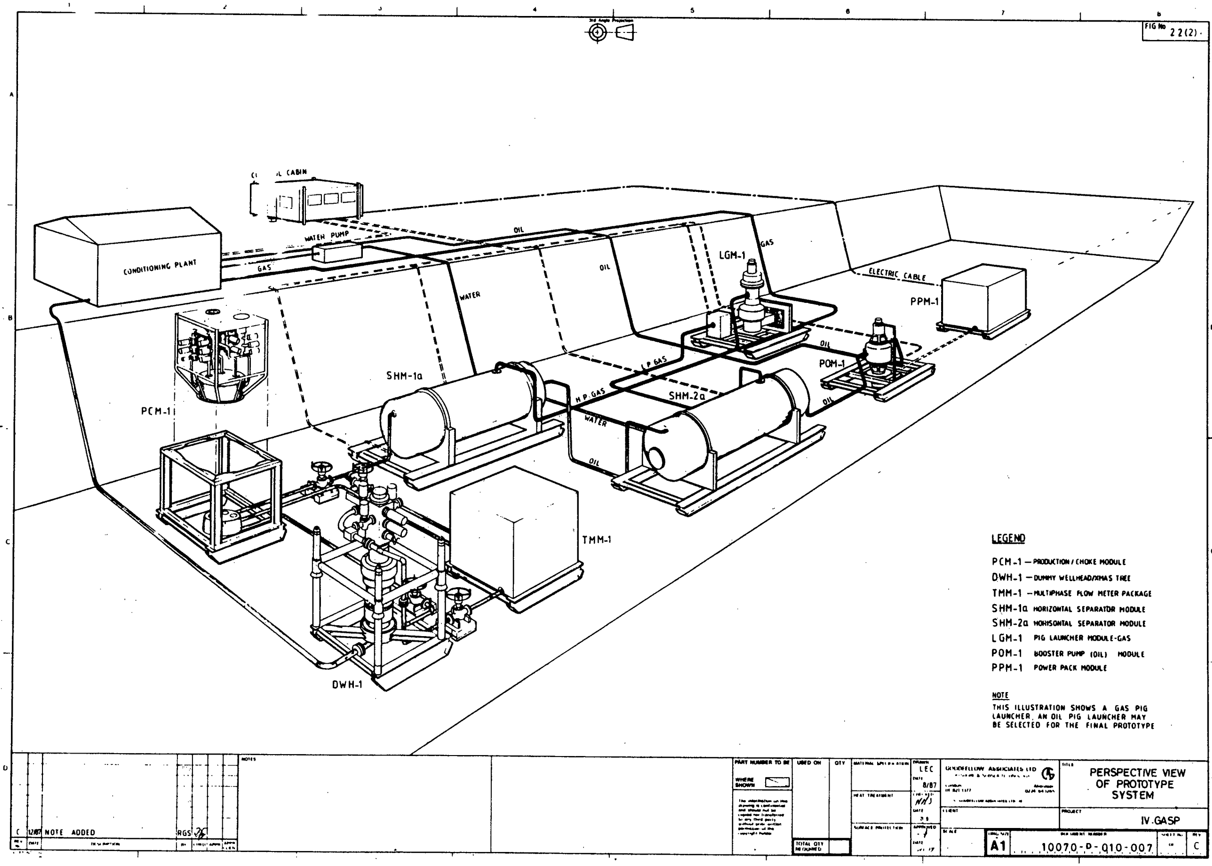


Fig.7. Dry dock layout of dry/wet testing of a prototype system

FIGURE 8

GA-SP CAPITAL EXPENDITURE COSTS

OIL PRODUCTION; 30 KM; 4 PRODUCTION; 4 WI; WATER DEPTH 300M; OIL PIPELINE 12" x 20Km; TIE-IN FLOWLINES 30Km; 12" GAS; 8" WATER; 2" CINJ; UMBILICALS; RESERVOIR DEPTH 3100M; FIELD LIFE 7 YEARS.

CA1 – FIELD DEVELOPMENT PLANNING

CA2 – PROJECT MANAGEMENT

CA3 – DEVELOPMENT DRILLING

CA4 – PRODUCTION CONTROL PLATFORM AND SUPPORT FACILITIES

CA5 – EXPORT FACILITIES

CA6 – SUBSEA PRODUCTION FACILITIES (SEPARATION/BOOSTING)

TOTAL	CA6	£M22.5

WITHIN PARTICULAR	- STRUCTURE	£M2.5
	- HEADER/MANIFOLDS	£M4.6
	- SEPARATORS	£M4.0
	- FLOWMETERS	£M0.8
	- PUMPS	£M1.2
	- CONTROL SYSTEM	£M6.1

ETC.....

CA7 – WELLHEADS AND TREES

CA8 – RISER SYSTEM

CA9 – INTRAFIELD FLOWLINES AND UMBILICALS (MATERIALS)

CA10 – UNDERWATER WORK SYSTEMS

CA11 – OFFSHORE INSTALLATION – STRUCTURE, FLOWLINES, PIPELINE

TOTAL	CA11	£M15.3

TOTAL ESTIMATED CAPEX =	£M136.3
+ CONTINGENCY =	£M150.
OVERALL TOLLERANCE =	22%

11. Design procedures to minimize lifetime costs

P. M. BLAIR-FISH, MA, PhD, MICE, DMS, G. H. G. LEWIS, BSc, FICE, MRINA and R. BOARDMAN, MIMechE, MWeldI, John Brown Engineers & Constructors

SYNOPSIS. The lifetime cost of an offshore installation includes costs for design, fabrication, installation and eventual removal. Strategies are outlined both to minimise overall cost and also avoid unexpected costs, by effort at the design stage. Examples are drawn from procedures evolved for the design of substructures. The procedures aim to ensure that cost-effective solutions are adopted, and corporate experience is used. Ease of fabrication, offshore installation, and especially underwater inspection and maintenance must be remembered. Quality assurance is used to ensure that standards are adhered to, specific procedures are identified, and evidence is recorded that procedures are being followed.

INTRODUCTION.

1. Offshore structures are commonly compared by their weights, because weights are often a useful guide to costs. Every extra 10 tonnes of topsides equipment needs (roughly) 8 tonnes of extra topsides structure and 3 tonnes of extra substructure. However, once plans are set to develop an offshore installation, the pursuit of minimum weight is not necessarily always the same as the pursuit of minimum cost. To achieve minimum overall costs, the whole lifetime expectancy of an offshore installation must be considered:

DESIGN (feasibility, concept, preliminary & detail)
FABRICATION
TRANSPORTATION AND INSTALLATION
HOOK-UP AND COMMISSIONING
OPERATION
REMOVAL

Costs are reduced if the cost of each item is minimised. However minimising the cost if any one item alone, especially the engineering design, is unlikely to lead to least overall cost.

COSTS FOR A SUBSTRUCTURE

2. Typical costs for a lifted jacket supporting Production, Drilling and Quarters topsides in 100-150m waterdepth in the Central North Sea are:

			£'000'000s
DESIGN AND MANAGEMENT			3
MATERIALS:	Steel Plate	4)	
	Appurtenances	3)	9
	Piles	2)	
FABRICATION:	Jacket structure	20)	
	Appurtenances	6)	30
	Piles	4)	
INSTALLATION			8
INSTALLED COST			50
INSPECTION AND MAINTENANCE			5

Annual inspection is assumed to cost the equivalent of one week of diving time per year. Removal costs are hard to quantify, because future crane vessels are likely to be able to remove most topsides and substructures in single pieces, at a small present cost.

3. This paper concentrates on the ways in which substructure costs can be reduced, and the design philosophies required to minimise costs. Costs can be reduced by:

* innovative concepts
* avoidance of errors
* design to minimise fabrication, installation and in-service costs.

4. Typical unit costs are
(ref. 1): £27/hour for engineering design

£400/t for steel plate
£1000/t for simple fabrication
£3000/t-6000/t for complex fabrication

£100/m for MMA fillet welds in shop
£400/m for MMA butt welds in shop
£180/m for SAW butt welds in shop
£900/m for MMA butt welds in the field
£250000/day for an SSCV

and £20000-50000/day for diver inspection.

Therefore, 1 tonne of fabricated steel costs as much as 3-4 man-weeks of engineering. Also, one day's hire of a large offshore crane vessel costs as much as 5 man-years of engineering.

5. The cost of mistakes is very high. The benefits of additional effort on engineering are generally much cheaper than the cost of errors. Errors are reduced by following procedures that not only ensure that designs are properly checked by experienced engineers, but also ensure that proper lines of communication and organisation are set up, and that adequate records are kept. Also, by drawing on corporate experience, the costs of fabrication, installation and operation can be reduced. The following sections illustrate known examples from the design of fixed substructures, and describe the procedures developed to learn from known errors and run projects in an organised manner.

OBJECTIVES OF DESIGN PROCEDURES

6. Design procedures to minimise costs need to:

* ELIMINATE ERRORS
* ACHIEVE QUALITY = FITNESS FOR PURPOSE
* ASSURE (CONTRACT REQUIREMENTS MET
(DESIGN IS SATISFACTORY
* ENSURE A PLANNED SYSTEMATIC CONSISTENT APPROACH.

7. Typical procedures for substructures design are illustrated in Fig. 1. Not all procedures are needed throughout the design process; for example, a procedure for change control is unnecessary in the early stages of conceptual design. However, early effort on review and agreement of scope of work, criteria, and design premises and specifications pays dividends later. The design specification should be reviewed together with the scope of work at the start of a project. After that review, those running the project understand not only what they have to do and what deliverables are to be produced, but also that design criteria are identified and missing information is flagged.

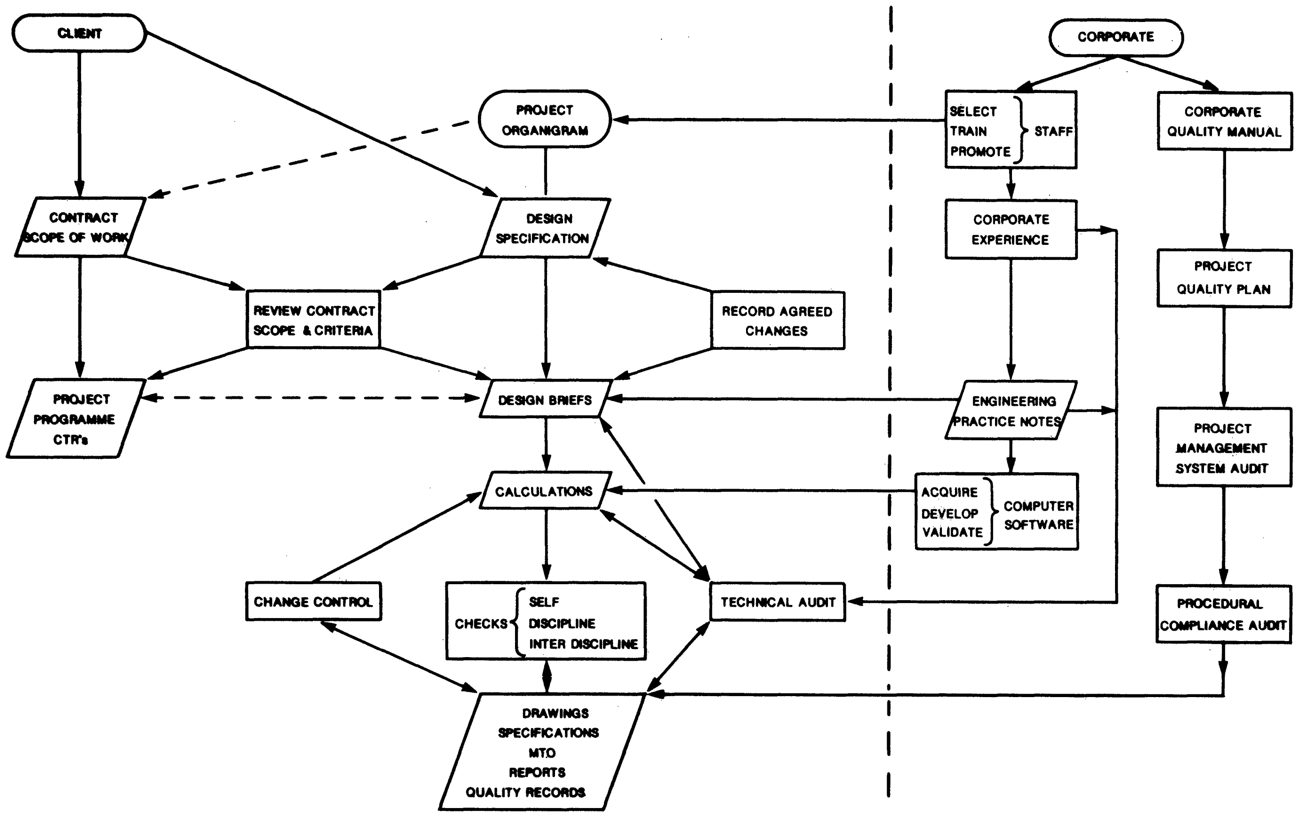


Fig 1 Design Methodology

8. The project quality plan identifies the procedures required for the project's quality management system. A typical list of procedures used on a project would be:

Quality Plan
Contract Scope and Design Criteria Review
Project Numbering System
Project Filing System
Co-ordination Procedures
Design Briefs
Design Calculations
Computer Input and Output Checking
Checking and Approval of Design Documents
Design Changes
Document Control and Records
Software Quality Control
Technical Audits
Quality Audits
Corrective Action
Quality Records

9. Co-ordination procedures define the control of correspondence on a project, whether generated internally or externally. Topics covered include (i) writing of letters, internal memos and telexes; (ii) recording of telephone conversations; (iii) taking minutes of meetings; (iv) making out visit reports; (v) internal distribution of documents; (vi) transmission of documents.

10. Adoption of a standard filing system ensures that records can be found even after a project has been closed down.

DESIGN BRIEFS, PREMISES AND SPECIFICATIONS

11. A design specification summarises data and criteria supplied by and agreed with the client, including the standards and codes of practice to be used on a project.

12. Design briefs are written for each major activity. The first design briefs were produced in 1978. They provide a clear statement both to the client and to each member of a design team <u>how</u> an analysis or design should proceed. They are produced by the lead engineer responsible for the activity, and confirm his understanding of the scope of work, the theory and computer programmes to be used, and all assumptions. Each design brief should be produced in a standard format and contain:

* GUIDELINES FOR ANALYSIS/DESIGN
* ECHO SCOPE OF ACTIVITY
* DESCRIPTION OF ELEMENT / SYSTEM AND ITS FUNCTIONAL REQUIREMENTS
* COMPUTER PROGRAM / MODEL
* DESIGN CHECKS / ACCEPTANCE CRITERIA
* MATERIAL PROPERTIES
* CODES OF PRACTICE
* SOURCES OF DATA / ASSUMPTIONS
* INPUT OF CORPORATE EXPERIENCE

13. Experience from previous projects is given to a project (see Fig.1) by:

1) assignment of experienced and qualified staff who have been selected, trained and promoted to levels within their capability

2) corporate experience from previous projects, which can include both advisory and mandatory do's and don'ts as engineering practice notes

3) supply of appropriate validated software

4) technical reviews and audits during the project.

14. The most important element in any design team is the quality of the people in that team. They must have sufficient experience to do the job but not so much that they are no longer motivated: each new task must be a small, but acceptable, challenge. Their career and training needs must be identified in an organised manner, typically by an annual performance appraisal. New staff must be interviewed by managers who have been trained in interviewing. Qualifications and experience must be checked. Most companies have established procedures for recruitment and career development.

15. Corporate experience from previous projects should not merely be informally available from a few senior engineers who happen to be attached to the job. Many designers can think of mistakes or poor decisions which occur in successive projects, purely because someone picked up the drawings from the last job and carried forward the error. John Brown have a rapidly updatable set of abbreviated guidelines on what constitutes "good practice", which senior engineers write themselves but are approved by the head of department.

16. The use of computer software should not relieve engineers of their responsibility to check basic principles by hand. However, it is not possible to verify every detail in a large and complex computer program on each project every time it is used. The engineer needs some reassurance that basic checks have already been made on the program before corporate acceptance. It is possible to use specialised computer software development control systems (configuration management programs) to record when a program was last validated and provide this data to the user each time the program is accessed. Such validation control software refers back to the paper files where the worked examples used for the validation may be found.

17. A technical audit is an independent review by engineers who are not part of the project team but who have sufficient experience to comment constructively on each of the key disciplines within the project. The objective of the audit is to answer the following questions:

a) Is the design sound?

b) Are contract requirements met?

c) Have mandatory engineering practice notes been complied with?

d) Are there any recommended improvements?

18. The audit produces a report confirming which documents have been reviewed, what questions were asked of the project team, what answers were given, and what action is required. In a systematic approach, actions are maintained on a "punch list" and chased up by the project QA engineer until they are closed out.

CALCULATIONS, DRAWINGS AND SPECIFICATIONS

19. To avoid errors, there must be calculations or analyses for each item of a structure. Also, those calculations and the drawings of the item that is to be built should be checked first by their originator, and secondly by another engineer of at least equivalent knowledge and experience. Thirdly, an interdiscipline check should be performed. Interdiscipline checks also apply to the input to analyses, especially where one discipline supplies input to analyses performed by another. For example, the naval architect must check that the structural analysts are using the correct motions in a transportation analysis.

20. All documents to be issued outside a project receive a final check before management approval. Checks on drawings and specifications that form the basis for a bid package are especially important. Check lists ensure that known errors are not repeated. Systematic checking by coloured highlighting of each item of a drawing or computer file ensures that nothing is missed. Changes to any design document must also be reviewed, checked, controlled and documented as for the original.

21. Procedures are used to ensure:

* systematic and uniform format, indexing, preparation, checking and collating of design calculations
* proper checks on computer input, before running a computer program. Computer output must also be checked, to ensure that results are sensible.
* records of checking and approval of all design documents. Responsibilities for interdiscipline checks, and required level of checks, are defined in advance.

QUALITY ASSURANCE

22. A quality assurance management system ensures that all statutory laws and consensus standards (e.g. ref.2) including clients standards are recognised and complied with by use of existing company procedures and, where applicable, by specific project procedures. The procedures are linked together and formally presented in a project quality plan.

A quality assurance management system then provides for audits to ensure:

* that the project management system is as detailed in the quality plan approved by the client
* compliance with procedures identified in the project management systems
* technical audits
* safety audits

23. Quality assurance seeks evidence that procedures exist and are being followed. The procedures outlined above can be flexible but controlled. Ideally, the procedures should be written by those who are to apply them, so that they are appropriate to the task. However, for a uniform approach, most projects use standard procedures.

24. Procedures reduce overall costs by ensuring that past mistakes are not repeated and also that new concepts and documents are reviewed in an environment that asks "what is different?"

25. All procedures used on a project relate to quality, because they provide a clear planned systematic approach and produce objective evidence that good working practice has been achieved.

26. QA also seeks evidence that projects are organised with clear lines of responsibility.

27. Overall, the additional effort of working to defined procedures requires only about 5% extra project man-hours, plus an additional 5% hours for technical audit and quality assurance surveillance.

28. Specific procedures used by the project QA engineer are those for quality audits and corrective action.

29. Quality audits are documented reviews to confirm that procedures are being followed and are not to be confused with independent technical and safety audits.

30. Corrective action requests are forms prepared by the project QA engineer that outline non-conformances identified during quality audits or routine surveillances. Project management is required to take action to ensure that deficiencies are corrected.

31. Finally, project quality records provide a complete listing of a design, and all the verifications, from the initial design specification through the various design stages until the completion of the project.

DESIGN

32. Fixed jacket structures have been used for most developments in the British sector of the North Sea. Developments such as lift-installation of jackets weighing up to 10,000 tonnes for water depths of up to 175 metres (see Fig.2) keep the fixed jacket structure economic.

33. One of the most vital functions of an offshore structure is to support the conductors through which the wells are drilled. Design of conductors and the guides that support them involves three disciplines:

* drilling
* facilities
* substructure.

34. Responsibilities and interfaces, particularly agreement on loads, locations of supports, design codes and criteria, is essential. There are instances of 20" conductors installed in guides designed for 26" or 30" conductors, causing a need for restraints to be retrofitted offshore. Omission of a vital level of guides, owing to a misunderstanding between substructure and facilities designers, can be expensive if conductor guides have to be installed offshore.

35. Costs can be saved by:

* predrilling wells through a subsea template, especially when hire rates are low for mobile drilling rigs

* reducing wave loads by reducing conductor diameters, use of anti-marine growth coatings, or close spacings to achieve shielding.

36. If risers and caissons are fixed to the jacket structure at more than one plan level, they can act as struts between plan levels when the jacket deforms under the weight of topside loads. Therefore, all risers and caissons must either be fixed at one level each, or be explicitly modelled in jacket analyses, especially in-place and fatigue.

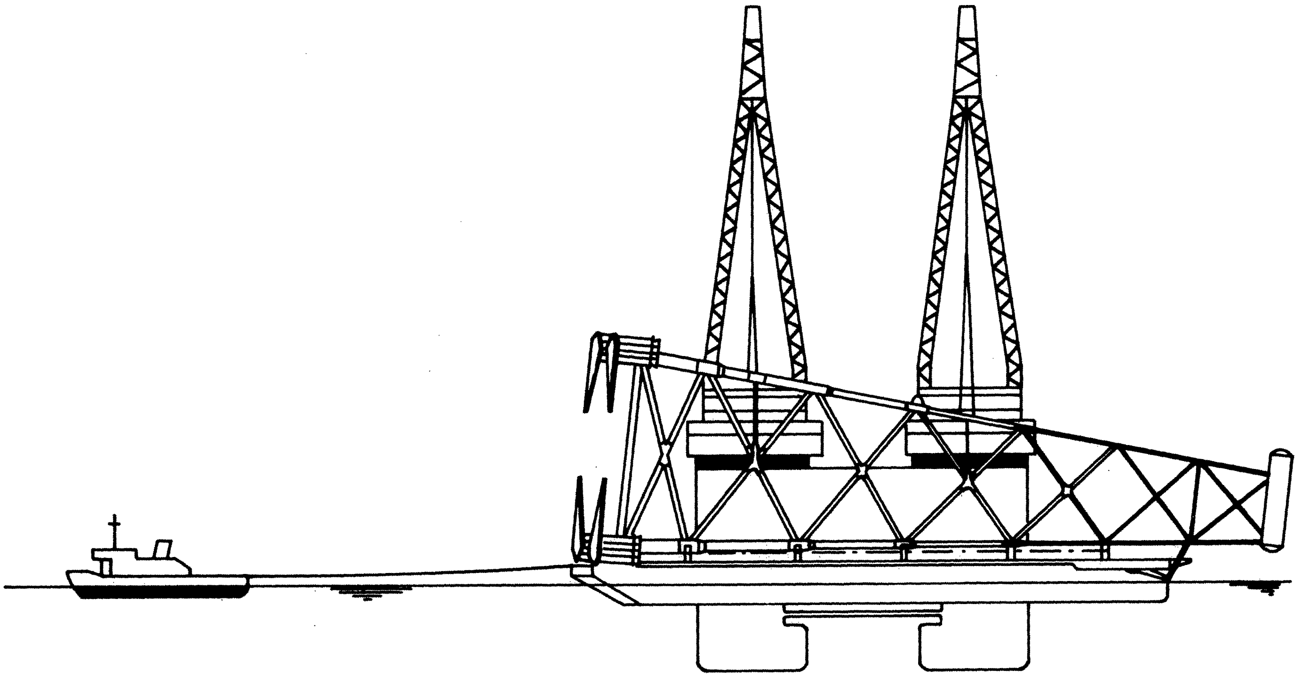


Fig.2. 10,000 tonne lifted jacket

37. Jacket structures can be protected from potential impacts from supply vessels so long as requirements for such protection are set early in the design. For supply boats of up to 5000 tonnes displacement, braces can be designed to survive operational impacts of up to 0.5 m/s, and legs to survive accidental impacts of up to 2 m/s. Design to such criteria may simply require stronger braces in the splash zone and reinforcing of the legs by either additional wall thickness, or grouted inserts, or mass concrete infill. Strengthening a structure that is already in fabrication or installed is considerably more expensive.

FABRICATION

38. Fabrication costs can be reduced by:

* identifying and analysing the likely sequence of erection at the design stage
* avoiding extensively heavy stiffening, or wall thicknesses outside the range of experience of most bidders for the fabrication contract
* use of through thickness tested plate for all jacket steel, which can save on welding and plate handling
* use of rolled Tee stiffeners, for example in buoyancy tanks
* ensuring adequate access for welding and inspection
* greater attention to fit-up to reduce mismatch, especially at closure welds
* use of fillet welds in areas not sensitive to fatigue
* classification welds by their required standard of inspection

The latter two options require more design effort but reduce overall costs.

39. Additionally, fabrication costs are reduced if the design is completed before inviting bids for fabrication. Changes after drawings have been issued for construction should be avoided.

TRANSPORTATION AND INSTALLATION

40. Transportation steel can be unintentionally underdesigned if motions used for analyses are not carefully checked by the naval architect who predicted them. Conversely, savings may be made if design sea states for transportaton are related to the exposure time duration for the tow.

41. Installation contracts are commonly let as lump sums. Therefore, costs are reduced if installation contractors perceive that their task is straight-forward, and the potential for claims against the client company is minimised. For jacket installation, the two most time consuming operations are commonly piling and grouting.

42. Pile installation has been speeded by the development of underwater hammers, notably the Menck MHU1700 and its derivatives. Underwater hammers shake jackets as well as piles. Therefore attachments on and close to pile sleeves, especially anodes and grout piping, have to be checked for pile driving vibrations.

43. Grout systems for pile to sleeve connections are now being designed to minimise effort and costs both at the fabrication yard and offshore. Specifically:

* packer inflation systems should be tested in their entirety, with careful control of tolerances on packer protection shims

* grout feeder pipes need not be left on a jacket structure after installation: grout pipes can run either through removable caissons, or as flexible lines handled by a diver or ROV.

* grout density can be reliably monitored by a source and detector attached to an ROV which then "sniffs" the density of grout in the overflow pipe. This method avoids the need for sources and detectors at each pile sleeve with fixed wiring to the surface.

INSPECTION & MAINTENANCE

44. Good design should ensure that a structure is designed for fatigue, protected against corrosion, and that it can be easily inspected.

45. Design procedures for fatigue are well established. Fatigue lives are checked not only at nodes, but also at closure welds and for stiffeners and attachments. Fatigue failures are known to have occurred on secondary bracings

not designed for fatigue and also from access manways which were not reinstated to the same standards as other structural closure welds.

46. Cast nodes now offer considerably lower stress concentrations than plated fabrication. To date, the additional cost and lead time for castings limits their use to nodes where a fabricated node cannot achieve required fatigue lives.

47. Corrosion protection systems need to be designed for easy verification of in-service performance. Monitoring of electrode potentials by divers is expensive. In-service inspection is considerably cheaper if:

* inspection can easily be completed within the annual maintenance shutdown of a platform, for example by having fewer nodes to inspect

* ROVs are used instead of divers, or better still hard wired or acoustic telemetry instruments

* the structure has inspection aids such as underwater markers, and all underwater attachments are designed to avoid snagging of diver or ROV lines.

* accurate as-built records are available including base line surveys of wall thicknesses at locations where thicknesses are later to be checked to determine corrosion rates.

CONCLUSIONS

48. Costs can be saved not only through innovative concepts, but also through a determined approach to minimise errors and use experience to reduce costs in fabrication, installation and service. Additional engineering at the design stage costs less than offshore errors. Therefore, it is not only 'what' is designed, but 'how' it is designed that is important. Procedures can help to reduce costs, especially by formaly identifying interfaces and applying previous experience.

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12. Cost effective quality appraisal

P. R. PASSEMARD, QUASCO

SYNOPSIS. Ten major UK oil and gas operators have achieved significant cost savings by pooling their resources for carrying out quality system and production capability appraisals on their suppliers. The paper describes the background to the formation of QUASCO, the benefits achieved and highlights some of the problem areas found in suppliers' quality systems.

COST EFFECTIVE QUALITY APPRAISAL

The drop in the price of crude oil during 1985/86 resulted in the brakes being applied to virtually every North Sea project. Those that were well advanced were generally allowed to continue on the basis that significant change, or in extreme cases abandonment, was uneconomic versus continuing with the planned programme.

Projects that were only at the planning or very early stages of implementation fared less well. They were generally stopped pending a complete re-appraisal of the economics and to allow time for some longer term trend in oil price movement to develop. That of course has now happened but in the meantime there has been a fundamental change in the way in which projects are assessed, developed and implemented.

On the economic front the most significant change is the inclusion of a "disaster" scenario in the assessment. Projects have always had to be robust over the expected range of crude oil and product prices but now there is the added requirement that they at least breakeven in the "low price scenario" of oil at $10-12 per barrel.

This extra dimension has had the effect of eliminating any fat there may have been in projects and they are now lean and pared to the bone. The general uncertainty has also tended to reduce the size of projects, with investing companies going for smaller, fast payback ventures that will limit their exposure and can be more readily managed.

In this environment the importance of getting it "right first time" is absolutely crucial as even fairly small upsets, caused by a need to rework a piece of equipment or re-design a component can seriously affect the much tighter margins to which most companies are now working.

Faced with tight projects in the past the traditional response of most project managers was to increase the level of inspection and monitoring throughout the manufacturing and installation stages but this has proved to be uneconomic and does not address the more fundamental aspects such as good design and reliability.

In addition due to the marked decline in activity and the general business squeeze over the past 3 years, most oil and gas operators and the contracting companies who service their needs, have made major reductions in staff. In many cases there are now not the people around within the organisations to effectively carry out the inspection work and availability from agencies tends to be of variable quality and expensive.

The result has been that more and more companies and project managers are adopting the proactive ideas of quality assurance which puts the responsibility for ensuring that goods and services are "fit for purpose" firmly back with the manufacturer and supplier. It requires that a supplier demonstrate his competence in controlling <u>all</u> his activities and does embrace the vital aspects of good design and reliability in operation, that inspection alone cannot address.

The cost of implementing a quality appraisal programme to underpin and service a project procurement activity, by assessing the capabilities of potential suppliers, can be considerable when there may be several hundred such assessments to be carried out. Usually there are very tight time deadlines to be met and many engineering manhours can be expended in trying to achieve this. During the very hectic days of 1983/84 when project activity was at its height, and expected to increase even further, costs for such activities were measured in millions of pounds per year.

A very high level of appraisal activity by a number of end users also presents problems for the supplier, who may be subjected to multiple appraisal, with all the potential customers ostensibly appraising to the same standard, but in reality perceiving problems in slightly different ways, with a corresponding divergence of opinion when recommending corrective action.

It was during such a period of very high activity in 1984 that the major oil and gas operating companies were challenged by the suppliers to get their house in order and to reduce the appraisal load to which they were being subjected. Shell picked up this challenge and after determining the interest and support of the other operators took the lead in a combined activity which led to the formation of QUASCO.

The concept of "QUASCO" is that oil and gas operators with a common interest in quality appraisal should pool their resources and share information which results in a significant cost saving to themselves and with tangible benefits to the supplier as well - the most important being a reduction in the number of appraisals.

QUASCO has two main objectives. The first is to carry out quality system and production capability appraisals on vendor companies who provide services, materials and equipment to the oil and gas industry. The second is to establish and maintain on behalf of the Members a library of appraisals and operational data of vendors' quality and production capability performance.

Since inauguration in 1985 QUASCO has carried out over 350 appraisals covering a very wide range of British Industry from small companies employing 15 people up to those employing many hundreds and ranging from steelworks to software houses. Some appraisals have been carried out on the Continent although this has been a relatively small activity amounting to 5% of the total workload.

QUASCO carries out appraisals at the request of its Member Companies, so a supplier cannot, on his own, initiate an appraisal. It is planned that a supplier would be reappraised after 2 to 3 years with possibly an interim visit, to follow up on any serious problems that were identified during the first appraisal.

QUASCO does not approve a supplier, his product or service, but provides detailed information that the

Member Companies can use to decide how they wish to do business with that particular supplier. Most Member Companies take the QUASCO information and from this produce a vendor rating that provides one element of a procurement decision. Such information can be made available to a Member Company's agent.

The QUASCO concept is a very cost effective way of carrying out quality appraisals on a large number of suppliers.

The costs of operating QUASCO are shared between 10 Member Companies and the financing arrangements are such that within certain constraints Member Companies can pitch their level of offtake of appraisal reports and consequently their subscription rates to match their operating needs. This is important as our Member Companies range from those that have mature operations to others that have still to enter the field as operators in their own right. Compared to carrying out the same level of activity in isolation Member Companies see their costs cut by up to two thirds.

QUASCO's cost effectiveness is further enhanced by its library of data on suppliers. The basis for this library, which now contains quality system and production capability information on some 900 suppliers to the oil and gas industry, was originally donated by Shell, with the agreement of course of the suppliers. This has been added to by reports received from British Gas and other Member Companies as well as those generated as the result of QUASCO's own appraisal activities. If a Member Company now carries out an appraisal on a supplier it is on the understanding that the report will be released to QUASCO for possible circulation to other Members, thus cutting out duplication.

The use of the library, providing the data is comprehensive and up to date, should prove to be a major cost saving for project teams. They can now obtain the information they require, when formulating bid lists or assessing a potential supplier, without carrying out a large number of appraisals, and at a fraction of the cost and manpower effort.

Apart from the cost advantages of not "going it alone" QUASCO has flourished because it satisfies a need. End users require independent appraisal of a supplier's quality system that examines those areas that are relevant and of particular interest to the oil and gas industry. QUASCO reports meet that need and provide detailed information on the strengths and weaknesses of the system that allows a customer to exercise their own judgement and take decisions on whether, and how, to do business with that supplier. The information allows determination of the monitoring and inspection level that is appropriate and can be used as a tool for upgrading a supplier's performance.

Suppliers also benefit from the QUASCO mode of operation. Apart from reducing the number of appraisals there is the obvious benefit that there is no charge made on the supplier although of course they have to provide the management and supervisory time to demonstrate the effectiveness of their quality system. There are additional benefits due to standardisation, as a QUASCO appraisal satisfies the needs of its ten Member Companies and avoids the problems of individual company interpretation of the reference standard. Our engineers also provide an element of informal consultancy when carrying out the appraisal. They are all on secondment from the Member Companies and therefore have first hand knowledge of the requirements for quality assurance in project and maintenance work. Small supplier companies in particular have found this highly beneficial.

During the two years of QUASCO's operation some patterns have emerged and it is possible to see, through appraising such a wide range of companies, the effects of the Government's quality drive that was set in motion back in 1979. There are very few companies now that are unaware of the requirements of quality management systems but it is interesting to note, that those companies that are in the most competitive sections of the market place, are usually the ones that have moved further and regard quality management as an essential tool that can offer a competitive advantage. They do not regard quality management as an extra cost to be passed on to the customer.

In general the effectiveness of a supplier's quality system reflects the importance that the Chief Executive and senior management place on quality. They are the ones who set standards and determine the attitudes lower down the organisation. Particular problems have been observed in the area of management review where the need to examine the operation of the whole quality system is not always appreciated.

Many quality management systems are shoehorned to meet the requirements of part 1, 2 or 3 of BS 5750 rather than addressing the need of the business. We frequently find important activities which have a direct bearing on the quality of the product, outside the quality management system.

Quality systems are often too complicated for the size of the business and demand too much in the way of procedures and documentation. This problem is usually the result of a quality system being installed for a supplier by someone outside the company, without the detailed understanding of the business.

Documentation and change control is another area where difficulty is often experienced. On the supplier's side companies are notoriously poor in maintaining adequate documentation and controlling changes to orders and specification to ensure that this is properly transmitted to the people who need to carry out the work. The customer on the other hand does little to ease these problems with excessive demands for paperwork covering every eventuality, the majority of which are redundant and thrown away at the end of a project, rather than concentrating on the essential requirements.

Although QUASCO has been in operation now for 2 years there is still a tendency for project managers within the Member Companies to do their own thing when it comes to quality appraisal and to "re-invent the wheel" with every new project. This has led to some continued duplication of appraisal effort but there is increasingly a realisation that QUASCO can meet their information needs and that money and manpower savings can be made. Most of the Member Companies now have in place a formal structure for handling the data provided by QUASCO to ensure that it is widely available to all project teams instead of being the preserve of one particular group.

An area that is not strictly quality assurance but is evident throughout the industry and continues to push up costs is that of "opinion engineering" and an insistence on company specification rather than adoption of a national or international standard. It has been shown that agreement can be reached on standards and procedures for quality assurance - why not in other areas where a real cost benefit could be realised.

In summary therefore the formation of QUASCO has demonstrated that it is a highly cost effective way of carrying out quality appraisals, where a group of companies have broadly the same requirements.

The oil and gas industry has been the first to benefit from this, but the concept is wholly transportable to other industries.

13. The role of the Offshore Energy Technology Board

C. P. CARTER, Offshore Supplies Office, Department of Energy

SYNOPSIS. Since the fall in oil prices in 1985, the search for cost reductions has become a matter of major importance for the offshore oil and gas industry. This is not a short-term phenomenon but a long-term requirement. The offshore supplies industry must respond effectively to it, including with a sustained R and D effort. This paper describes the role of the Offshore Supplies Office (OSO) in stimulating R and D involving the oil companies, the offshore supplies industry and government.

THE OFFSHORE SUPPLIES INDUSTRIES

1. The phenomenal growth of the North Sea oil and gas industry in the last 20 years has been matched by the development in the United Kingdom of an important very diverse group of industries supplying goods and services to the offshore oil operators. In the early days of the UK North Sea, the UK content of developments was typically around 40%. Today the figure is closer to 80%. The offshore supplies industries are major employers, particularly in the economy of Scotland. The turnover of the offshore supplies industries, even in the difficult market following the fall in oil prices, is around £2 billion/year.

2. The UK Continental Shelf (UKCS) is now a mature oil province with an extensive infrastructure of platforms, pipelines, shore terminals and supply bases. The UK's offshore supplies industries will in the future continue to serve a substantial UKCS market, but will need to look increasingly to international markets. About 30% of the worldwide offshore supplies markets is effectively open to international competition. So far the UK share has been small. The main prospects for the UK industry to serve this market lie in the provision of sophisticated equipment and services i.e. the "high tech" end of the market. Technology will be the key to success.

3. It is important to recognise certain key characteristics of the offshore supplies market. The oil companies are in many important respects very conservative. They place a high premium on proven success and reliability. Partly for this reason, many sectors of the market have been dominated for

many years by US oilfield technology. It is also a market subject to varying degrees of government influence in different parts of the world, including influence exercised through national oil companies. At the present time, the market is characterised by an intense squeeze on margins. The sector as a whole, though with some encouraging exceptions, is not currently attractive to risk capital.

RESEARCH AND DEVELOPMENT

4. In the UK, between £100m and £140m per year is spent on offshore-related R and D. The oil companies account for the larger part of this figure, between £70m and £90m. The government accounts for a further £20m - £30m, including research at universities, and the offshore supplies industry itself probably invests upwards of £10m/year in R and D.

5. Much of the oil companies' spending on R and D is to solve their own problems. Government has to spend on offshore safety R and D and in other fields, as well as in support of the offshore supplies industry. Nonetheless, something in the order of 20% of the nation's total R and D spend is of direct benefit to the offshore supplies industry.

6. The OSO maintains close liaison with the R and D programmes of the oil companies and encourages them both to undertake R and D in the UK (as opposed to, for example, conducting North Sea related research in the US) and to structure their programmes in a way which benefits the UK supplies industries. Encouragingly, there has been no evidence of a fall-off in total oil company R and D spending since the fall in oil prices. OSO have however been told by several oil companies of difficulties in identifying worthwhile projects to support in the offshore supplies industries. OSO can sometimes help oil companies to identify suitable partners, but does not regard it as its role to direct oil companies as to the specific research projects they should undertake. It is important rather that the oil companies develop autonomous R and D programmes which meet their own concerns and requirements.

7. As regards the offshore supplies industries themselves, there is unfortunately evidence that R and D spending has fallen off in the past two years, though it may now be beginning to recover. It cannot be stressed too strongly that the opportunities of the next upturn in the offshore market will be taken by those who have continued to invest in R and D during the difficult years, and who have in particular recognised the continuing importance which oil companies will attach to technologies which offer real scope for cost reduction

THE ROLE OF OSO

8. OSO's objective is to encourage R and D which will help to sustain and create a technically advanced industry, firmly anchored in the UK, capable of competing effectively both on the UKCS and on international markets.

9. OSO pursues this objective in four principal ways. First, it encourages the oil industry to become more closely involved in the R and D efforts of its suppliers. Second, it encourages a flow of information to the offshore industries about technological opportunities and the market for them. Third, it assists and advises UK companies in applying for help from the European Communities under the scheme for Technology Developments in the Hydrocarbons Sector (TDHS). Finally, it helps to finance high-risk R and D in offshore supplies companies, through a system of shared-risk financing, in which OSO's contribution is repayable through a levy on sales in the event of commercial success.

10. In developing its strategy, the OSO is advised by the Offshore Energy Technology Board (OETB), which is a group of senior respresentatives of the oil and supplies industries, chaired by the Minister of State at the Department of Energy. The role of OETB is not simply to advise on OSO's own R and D expenditure, which totals some £4m/year, but to act as a focus for a wider national effort.

11. The OETB has identified four priority areas, and 80% of OSO's spending is now concentrated on these. Subsea production systems is the subject of particularly intensive effort. OSO is funding a number of pre-feasibility studies, which are intended to lead on to fully fledged projects with oil company participation. The focus is on sub-systems which will be needed for subsea development of small, marginal fields in mature oil provinces.

12. The second priority area covers drilling and production technologies. In drilling, indigenous UK technology is not strong. Nonetheless, 12 specific areas for R and D effort have been identified, and projects for which funding has already been agreed include projects in directional drilling and a computerised drilling engineering and planning system. In production technology, a special group has been set up to identify areas of opportunity. Recent and current projects include work on the thermodynamic properties of gas condensates and volatile oils; the modelling and simulation of borehole logging tools; and the development of a permanently installed borehole temperature and pressure guage.

13. The third priority area is the weight and cost reduction of platform topsides. Last year OSO funded studies by Global Engineering on topsides design, and by Wimpey/Fulmer Laboratories on lightweight materials. These have already led to a number of interesting private sector initiatives. The future focus is likely to be on new materials (though it is not, of course, for government to encourage one material over another - rather it is to make the opportunities known so that companies can make informed choices), and on innovative designs of topsides equipment. In the latter area, a study on the scope for membrane technology offshore has just begun.

14. Finally, in exploration technologies, OSO is funding a study on the limiting factors in the accuracy of marine seismic surveys with a view to identifying R and D opportunities.

Other work is concerned with the improvement of 3-D seismic data acquisition, and the development of a new generation of seismic workstations.

CONCLUSIONS

15. OSO is convinced of the importance of a sustained R and D effort in the offshore supplies industries. The focus must be on the development of goods and services which enable oil companies to do the job more cheaply, in an era of low oil prices, and with increasing emphasis on small fields. The impetus to reduce costs runs through every stage of the process - from initial exploration right through to the final abandonment of offshore structures. The responsibility for the necessary R and D must lie primarily with those whose commercial interests are directly involved. But OSO will continue to advise, cajole and stimulate interest, and - where appropriate - help to fund innovative high-risk projects which hold out real prospects of eventual commercial success.

14. Cost reduction in offshore development projects

R. KVAMSDAL, Moss Rosenberg Verft a. s.

SYNOPSIS. Recent R & D-activities in Norway have to some extent shifted towards short-term projects addressing low-cost developments for oil and gas, both with respect to investments and operating expenditures. This is also the case for projects where public funding is involved.

PREAMBLE

1. Low oil prices combined with a wish to be able to develop smaller oil fields have lead to an intensive search for more cost efficient ways to meet both the initial investment as well as field lifetime. operation expeditures. Much of this activity is nothing else than engineering, but there is also genuine R & D involved.

2. Lowest possible topside weights and simple arrangement have always been important design criteria for all offshore installations. This has led to a comprehensive research activity over the later years, addressing topics like processes and process equipment, materials and structures. New concepts have also attracted large interest, particularly inspired by increased offshore lifting capacity. Subsea installations and subsea completed wells are other examples of new concept thinking, more recently also in combination with different types of floating production units. Monohull (shipshaped) or semisubmersible floaters are in focus, however, hybrid solutions based on jack-ups or even light jackets combined with floaters carrying the process equipment are being considered.

3. This presentation will in particular deal with R & D in Norway, and how public funds through NTNF (Royal Norwegian Council for Scientific and Industrial Research have been utilized.

4. For the sake of good order, it is emphasized that the views expressed are those of the author.

WHY R & D?

5. Fig. 1 below is an illustration of how the costs to produce 1 unit of oil and gas develop with time. Historically, one has been able to reduce these costs as time goes on, and it should be expected that this will be the case also in the future.

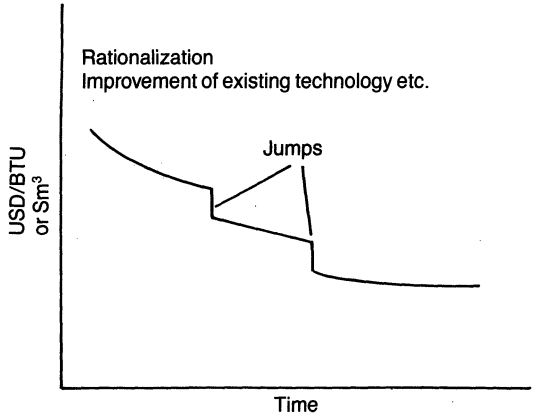

Fig. 1 Principle of cost development with time for production of oil and gas.

6. The gradual change downwards is the result of general rationalization, improvement of existing technology, and introduction of new technology. Better project execution and improvement of exisiting technology can be credited the larger part of the positive development. New technology has been, as a rule, only called in when the frame conditions are right. Such frame conditions can be due to reservoir or environmental particularities. Lately, the prevaling price picture has also inspired greatly to new solutions. A substantial new achievment can create a jump in the trend curve as indicated in Fig. 1. An important observation is that a lucky and good organization of an oil field development project can create similar and at least equally large jumps.

7. R & D should be expected to play a significant role in this process. It is, however, believed that the most significant contribution is rendered through long term improvement of the know-how and and general insight of the actors on the scene of petroleum development. It is therefore important that the same actors perform qualified R & D work, to the extent and with the problems the respective company can identify itself with in a natural way.

8. Education of qualified personnel can be achieved through participation in development-projects in the industry, as well as at R & D instructions and universities. A larger emphazis on the firstmentioned method is probably justified.

9. To-day, the interest for new and costefficient technology has focused on the more short-termed development projects, be it complete systems, or even more so, improvment of existing technology. New and genuine improvements as a result from R & D activities should be recognized, and the problems faced in this context could be as complex and challenging as the development of brand new technology, be it components or systems.

10. To develop a completely new system, may in itself be a straight forward task. To introduce it and see it applied in real life, is quite another issue. The users, normally oil companies as field operators, are often felt to take a standoffish attitude, claiming a.o. that new components or systems lack references. The market introduction of new tehcnology within the offshore field constitutes in itself a challenge that need to be adressed, and different initiatives have been taken, also in the form of dedicated R & D project!

R & D IN NORWAY WITHIN THE OFFSHORE FIELD

11. The amount spent on offshore related R & D in Norway and how it is financed over the latter years, is shown in Fig. 2.

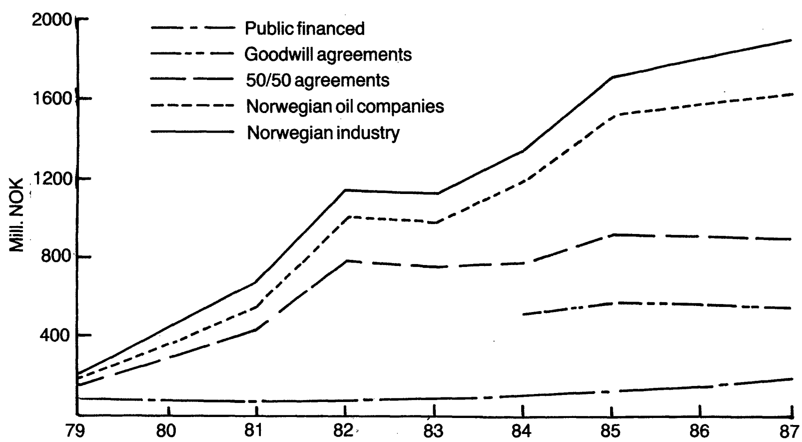

Fig. 2 R & D spending in Offshore Technology in Norway. (Updated as of Oct. 15, 1987)

12. The very first impression is that the effort is quite substantial, running to abt. NOK 1.850 mill. in 1987. It may also be derived that public funding, in all essentials through NTNF, stops at abt. NOK 180 mill., the contribution from the Norwegian industry (defined as those producing services and goods) amounts to abt. NOK 240 mill., while the remainder, some NOK 1430 mill. is spent by the oil companies. The actual work is to a large extent carried out by research institutes and by the industry as commissions given by the oil companies.

13. The boarder between R & D work and engineering may be diffuse. In large offshore development projects, however, a quite substantial amount of engineering is often required to identify a bottleneck calling for a research type of approach. It is important to limit the part of the work that is genuine R & D, because such work should be governed by other means than engineering (results, part results or milestones in stead of e.g. resources spent or percentage completed as usual for engineering projects).

14. "Technology Agreement" is an arrangement whereby oil companies, in particular the foreign ones, are encouraged to perform R & D - work in Norway, against certain benefits, like higher rating when applying for blocks and operator-ships on the Norwegian Continental Shelf. At present, there are two types, 50/50 agreements and the socalled "Goodwill Agreements". The former type implies that for a given license or concession on the Norwegian Continental Shelf, 50% of all R & D work associated with the development of said lisense shall be executed in Norway. The latter type is selfexplanatory, and not connected to any particular license.

15. NTNF has been given he task of evaluating and administrating the GW-agreement arrangement in Norway on behalf of the Government, specificly the Oil and Energy Department, who gives the auspieces for the administration of the GWA. Later instructions have indicated a public wish to turn these GW agreements more towards activities that can result in industrial products.

16. Offshore technology and associated research can truly be said to be one of the more multidisiplinary tasks. Its progress and sucess depends on the ability to use the best from information and material technology, structural and process analysis to mention a few. It is therefore in the best interest of Offshore Technology that the know-how

within these fields is kept up by adequate R & D, importation of technology, etc. High levels of multidiciplinary know-how are found in environments dealing with aviation-, space- and nuclear activities. Actors in offshore R & D approach said industry from time to time.

R & D WITH PARTICULAR EMPHASIS ON COST REDUCTION

17. Applied R & D in the offshore field should have as its primary target to reduce production costs for oil and gas. The sudden price fall for hydrocarbons a couple of years ago made the need for cheaper solutions imminently, if we at all should consider development of new fields. Slogans like "15-dollar techno-logy" was created, and "15" was soon replaced by "10". The possibility of suggesting new and cheap solutions, became more than ever before dependent on the ability to harvest on existing technology, more specificly how to use and to combine known technology elements in a new way. A new taxation system was adopted in 1985, which a.o. enhanced development of certain fields.

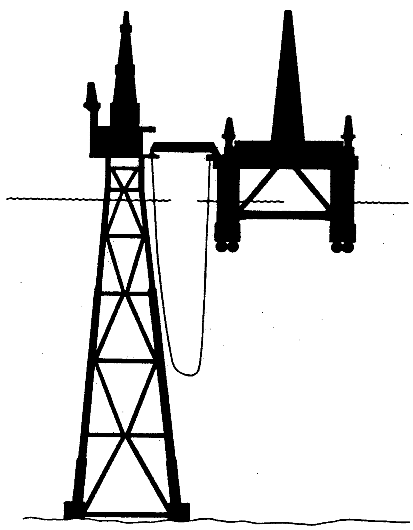

Fig. 3
Statoil's proposal for development of Veslefrikk

18. One of the best examples of such new thinking, is the present development of the rather small North Sea field Veslefrikk, Fig. 3. A light jacket for wellheads is used in combination with a catenary anchored semisub, carrying the process equipment. The cost reduction achieved on the installation itself is understood to be in the order of 75 per cent, compared with the original jacket solution.

Earlier research adressing jacket structures, floaters with anchoring systems as well as flexible risers and other connections has contributed to this realization. The research started so early that the different items had been tried out and evaluated in service. This underlines an earlier statement, namely that new technology has a long way to go before it is used. The Veslefrikk development is also an example of the wish to locate wellheads above see level, if by any means possible.

19. Subsea completions are found in connection with a number of North Sea fields. The costs, however, associated with a typical Norwegian well, have so far been tremendous, Fig. 4.

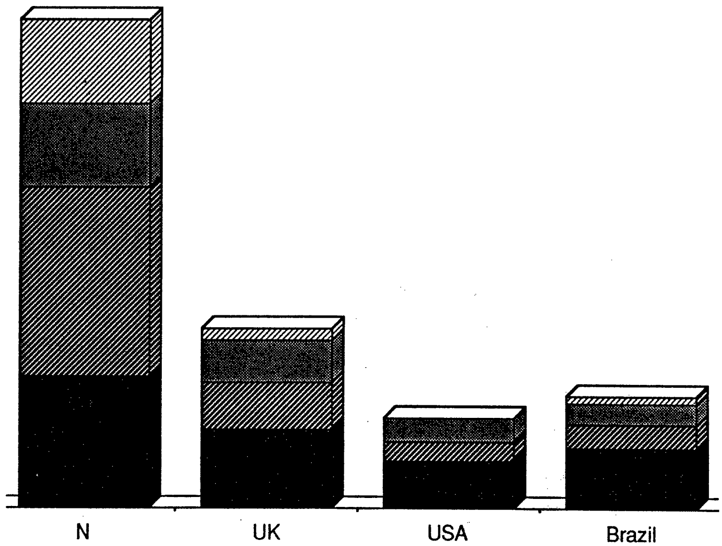

Fig. 4 Costs comparison, Subsea Well completions.

It is tempting to suggest that in this particular sector, R & D might have had the opposite effect of the good intentions, because we have rather seen a cost increase instead of a cost reduction over time. Appearently, subsea completions never came out of the stadium of experimental or prototype installations. There has been quite comprehensive R & D efforts in Norway, both on components and subsystems, like connectors, diverless intervention methods, as well as on total system integration, like the French initiative SKULD and Statoil's UPS. ("Underwater Production System").

20. The drilling and well completion costs are also included in the graphs in Fig. 4. Again, in Norway the figures here are quite high, compared with the other countries. Research has brought forward top drive, automated drilling processes, high-deviation drilling and even horizontally drilled wells are now within the reach. However, the new technology thus developed, is not in use to any larger extent. This is, as have been said earlier, to a large extent due to the conservatism in the field, and how development projects are organized. An efficient organization of the project, reflected in the contractual agreements, is expected to be a potential for substantial cost savings. Such savings can be of the same order as major technical break throughs like the concequence of the new generation of heavy lift ships.

COSTEFFICIENCY THROUGH NEW ORGANIZATION - AN EXAMPLE

21. NTNF sponsored in 1987 a larger project addressing potential cost reduction through new organization models. A comprehensive investigation into different technical solutions, organization models etc., were all related to a concrete, marginal field in the southern part of the North Sea. From the results, it become very clear that a substantial cost reduction can be obtained through a new organization of the entire process of developing and running an oil field, particularly smaller (or marginal) ones.

22. The best technical solution turned out to be a monohull floating production system, catenary anchored through a turret, and using a shuttle tanker to transport the produced oil to shore, while associated gas can be piped to a nearby installation with spare capacity, Fig. 5.

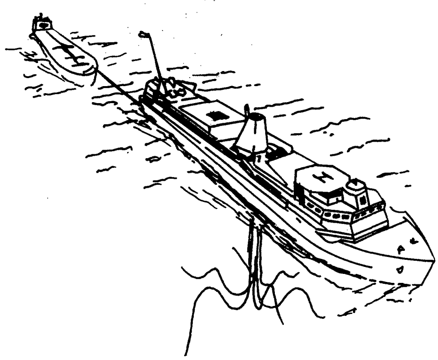

Fig. 5 Monohull floating production unit with shuttle oil tanker.

23. A redistribution of tasks, laid down in contractual agreements between operator and contractor (or a group of such contractors/entrepreneurs), can focus on leasing of production equipment, short development periode, integrated with or directly followed by the operation of the field, Fig. 6.

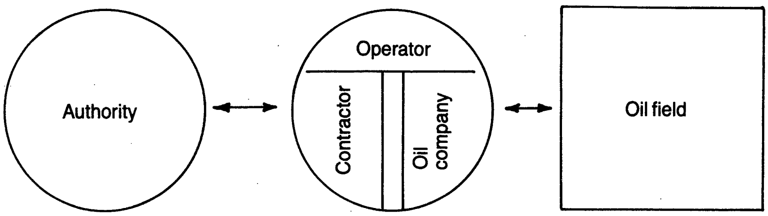

Fig. 6 Relations between operator and contractors/ entrepreneurs in a new mode of cooperation.

24. Part of the different risks can thus be carried by others that the operator. Through reuse of equipment, cuts in charter rates may be achieved. Such reorganized and simplified development would imply reductions in the order of 25 per cent alone, Fig. 7, referred to a break-even oil price in the order of USD 14.00 per barrel.

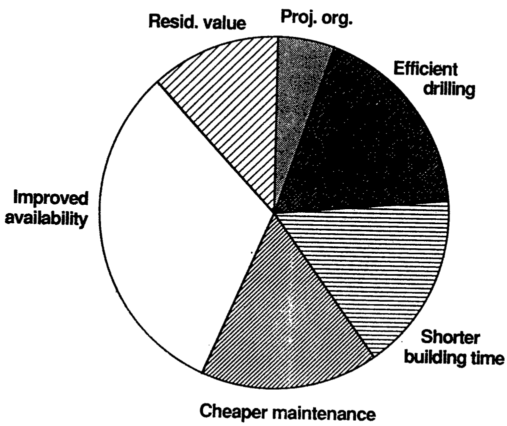

Fig. 7 Cost savings through new organization, distributed on the different elements of saving.

WEIGHT REDUCTION, EFFICIENT PRODUCTION METHODS

25. Large concrete structures have a relatively long history in the North Sea. Research into lighter and better concrets, as well as design, building and above all, installation methods have lead to considerable cost reductions. This has again resulted in consideration of concrete platforms for fields where simpler, even subsea solutions had been indicated. The competition between steel and concrete has become pronounced, to the benefit of cheaper solutions. Earlier, one may have heard that the large platforms will disappear in 10 years time, and be replaced by subsea completed field installation.

26. This picture has changed, since considerable weight reductions have been possible, mainly through offshore lifting of larger modules, and better and more cost efficient platforms, be it in steel or concrete. R & D on typical jacket structural features has been and is consentrated on optimization of the structure pattern itself, the nodes in different shapes and according to different production methods. Fig. 8 shows a typical jacket node.

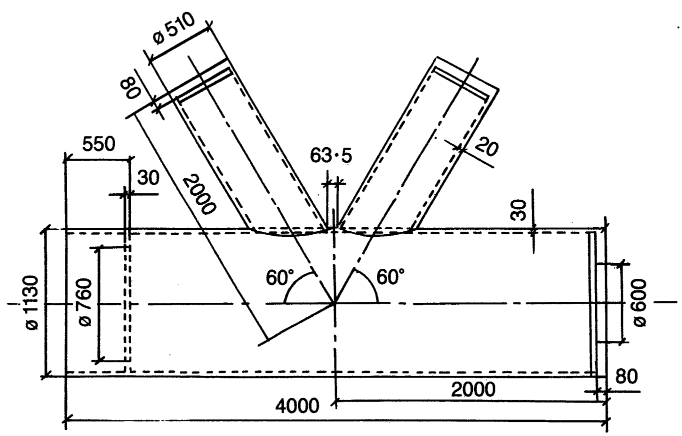

Fig. 8. Jacket node with dimensions (1)

As we have seen, the results from the research activities have already been applied with advantages.

27. Pipelines in non-metallic materials are used to some extent on platforms, and have also been identified as particularly promising for larger trunk lines as well as for the smaller in-field lines. A significant break-through may be as expected soon.

28. The price situation on the petroleum market has called for really substantial cuts in investment costs. Relaxation of availability requirements has turned out to be a source for savings, and simpler processes with simpler auxiliary systems have been developed.

29. Soon, we will probably also see the first accomodation quarter in aluminium. This material, which has a favourable weight/strenght ratio compared with ordinary structural steel, is expected to have a bright future as construction material.

PUBLICIALLY FUNDED R & D - PROGRAMS

30. Norway has gas discovers that will last for 120 years at present days rate of depletion, while the oil reserves have a duration of approx. 45 years only. Research in order to forward utilization of gas, both as an energy carrier and as a raw material, has attracted great attention. A government funded program has been started, called "SPUNG". (State Program for Utilization of Natural Gas.) It addresses chemical conversion to liquid fuels, LNG technology and gas fired power plants.

31. New programs in the process of being implemented, are

- Floating production systems
- Multiphase pipeline transportation
- Efficient drilling operations
- Automation and remote control

These programs will run for 3-5 years, and will be based on the principle of cooperation between industry, research institutions and universities, where the public funds in particular will be used as "seed money" to trig larger committments from the industry and the oil companies.

31. Significant for Norwegian research has been a large diversification and a split in many smaller projects. Now the time has come for concentration on fewer projects with well defined goals. International cooperation has also become more important. Norway participates e.g. in the EUREKA scheme, where several projects are within offshore technology.

32. As an example of a single, successful industrial project kicked off with NTNF seed money, is mentioned a gas meetering system by Kongsberg Offshore A/S, Fig. 9. (2)

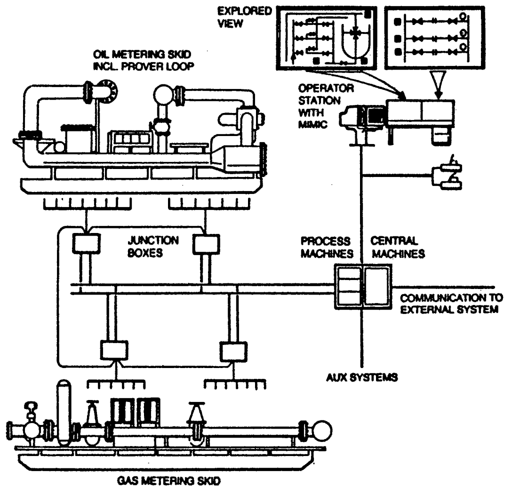

Fig. 9 Fiscal gas metering system

33. Efficient CAD/CAM/CAE-tools have already had a great impact when it comes to cutting production costs. R & D programs have addressed this topic over many years, continuing initiatives from the shipbuilding era. In recent years, a Norwegian/German bilateral program has attracted interest. Fig. 10 is an example of CAE used in a R & D project.

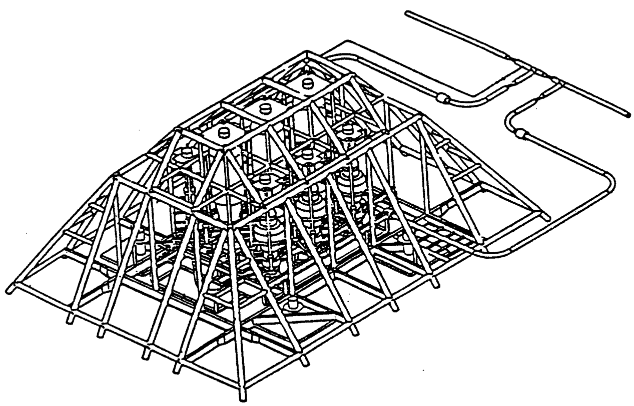

Fig. 10 Subsea booster station. Example of the use of CAD/CAE up front in a development program.

CONCLUDING REMARKS

R & D activities within the offshore field should first of all be planned for the long term effects. There should, however, be procedures to allow the more short term, market dictated efforts too. Potentials arising from new and more efficient ways of organizing, can result in savings of the same order as new technology, and is easier to implement.

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