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KEY CONSIDERATIONS IN THE DESIGN OF OFFSHORE PRODUCTION FACILITIES FOR ARCTIC OFFSHORE CONDITIONS

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ABSTRACT

For the development of production facilities in the Arctic, emphasis will be on the adequate design of structures and pipelines to resist the ice loads and on the requirements to a clean environment. However, the designers should take time to identify the most profitable development schemes by optimising the sales product from the field. This will put emphasis on the transport solution of the products and the paper calls for careful discussions of alternative transport solutions including pipeline transport and offshore loading schemes for stable oil and condensate products. Further, the paper highlights the needs for efficient project management identifying how the economic ale of a project will deteriorate if the costs are exceeded or if the schedule for the project for start up of production is being missed.

INTRODUCTION

Key considerations to be taken into account in the design of offshore production facilities for the arctic offshore includes knowledge about the conditions related to the physical environment (meteorological and oceanographical conditions) and the soil at the site as well as the actions exerted from waves and ice on the selected platform(s) to be placed at the location. Furthermore, the requirements of a clean environment are of key importance in the Arctic. These are the traditional considerations carried out by the engineers with civil and/or environmental background.

The sales products from the field will influence on the development solution and the offshore production facilities where main focus will be on the handling of the gas and unstable condensate associated with *oil production* and the condensate associated with *gas production*. The optimization of the product may generate additional valuable income, but the long distance to the market and the physical difficulty to construct

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terminals for export of unstable products may make an optimal field development particularly difficult in the Arctic.

For the transport to the market emphasis will be on the conditions for pipeline transport in shallow waters, shore approach solutions and offshore loading and transport solutions for stable oil and condensate products.

In relation to field development in the Arctic a discussion on the limitations for the extended use of existing installations, and the prospect of using subsea development solutions, have to be undertaken and a research programme aiming at understanding how less capital extensive development schemes could be achieved under arctic conditions would be welcome.

The optimal way of executing development projects for the Arctic must, furthermore, put emphasis on effective project management and use of local goods and services. In this respect it is important that the investors gain confidence that the project design phase and fabrication phase as well as the marine operations and start up of the facilities will be executed efficiently within the agreed cost and time schedule.

KEY CONSIDERATION FOR THE DESIGN OF PRODUCTION FACILITIES FOR ARCTIC OFFSHORE CONDITIONS

Conditions related to the physical environment and the soil at the site as well as the actions exerted from waves and ice on the selected platform to be placed at the location represent key parameters to be investigated to be able to design safe structures for a location. This applies in particular in the Arctic where the uncertainties in the estimate of the design ice conditions are particularly large and where the uncertainties in the ice properties also play a very important role for an accurate determination of the actions from the ice.

Furthermore, the requirements of a clean environment are of key importance in the arctic conditions and it should be considered whether a particularly high safety class is required for the design of arctic offshore structures for hydrocarbon production. The design engineers should also think about the environment in their work and be prepared to implement measures such as double hull platforms when oil is being stored at the offshore platform and cleaning of all ballast water that comes in contact with hydrocarbons (Gudmestad, 2003).

INTRODUCTION TO SELECTION OF TRANSPORT SOLUTIONS

Transport of hydrocarbons from offshore fields in the Arctic leads to large challenges, whether pipeline transport or ship transport is selected. In view of the very long distances from the Arctic to the markets for oil and gas products, transport will represent a substantial part of the capital and operational costs of the development. Operators, authorities and the public are, furthermore, concerned about the safety of the transportation and in particular of the environmental aspects of transporting the hydrocarbons to the market.

For the transport to the market emphasis will be on the conditions for pipeline transport in shallow waters where ice ridges and stamukhas could interfere with the pipelines, shore approach solutions and offshore loading and transport solutions for stable oil and condensate products

We will evaluate the different transportation schemes, their viability with respect to economy and safety as well as environmental matters. We will try to present recommendations on the way forward in the process of selecting the transport scheme for an arctic offshore development.

The sales products from the field will influence on the development solution and the offshore production facilities where main focus will be on the handling of the gas and unstable condensate associated with oil production and the condensate associated with gas production. Optimisation of the product may generate additional valuable income.

TRANSPORT OF THE PRODUCTS FROM AN OFFSHORE OIL FIELD

In view of the transport challenges, it is recommended that a careful analysis is carried out to select the product that will be delivered from the offshore location. For an offshore *oil field* it could be natural to process the oil to a stable product for delivery to a ship that can sail either directly to the market or to a harbour for transhipment. The stable oil and stable condensate products should possibly be mixed into one attractive product that can be delivered to any refinery. This will require offshore storage of the stable oil products. The associated challenges related to offshore loading where sea ice is present should, however, be considered and we propose that the submerged turret offshore loading buoy technology (STL technology, Figure 1) will have advantages over direct loading from a platform in the case the direction of drifting ice is changing rapidly as is documented from measurements of ice drifts in the Pechora Sea (Løset and Onshuus, 1999). This concern is particularly true if there is a possibility for the transport ship (tanker) to drift into the platform, see Figure 2.

The status for an ongoing research project to document the use of the STL technology under arctic conditions has been presented recently (Bonnemaire et al., 2003). The key idea is to protect the top of the loading riser interacting with the ice from being damaged by ice floes or ridges, see Figure 3.

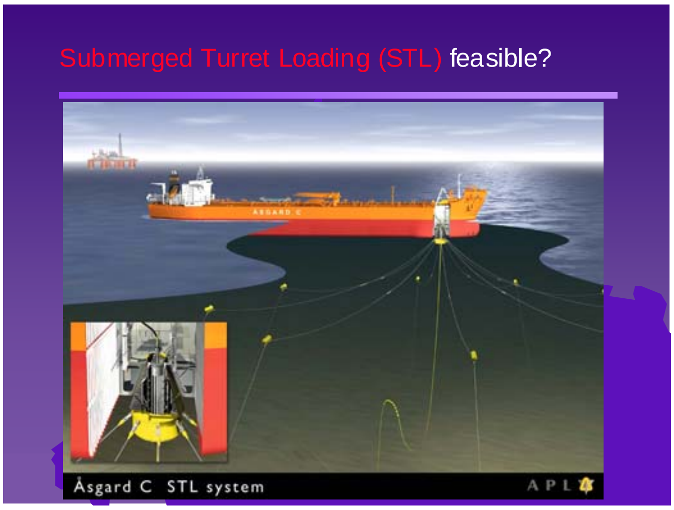

Fig. 1. Will use of STL loading be possible in ice

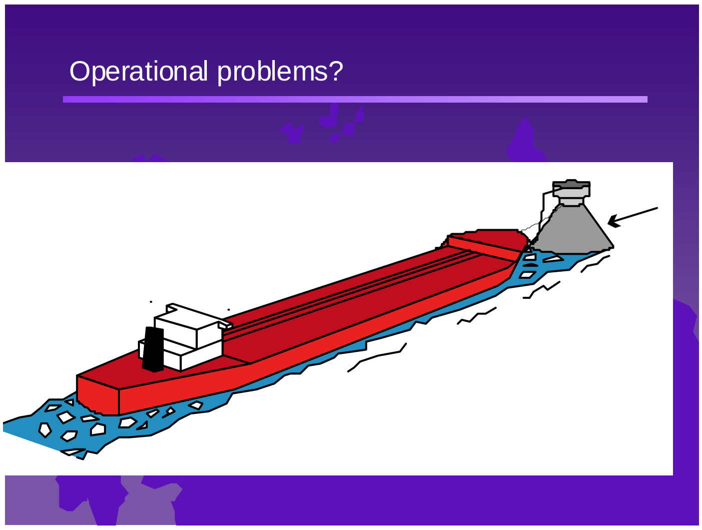

Fig. 2. Will the shift in ice drift direction cause operational problems for loading from a loading tower

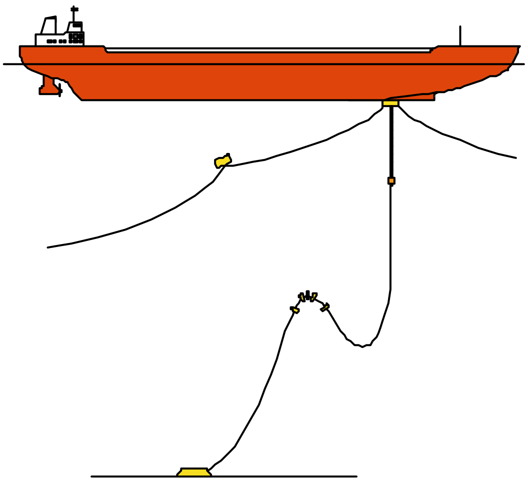

Fig. 3. Riser protection armour for ice infested areas

In shallower waters, the riser might have to be protected with armour over its whole length. When not connected to a tanker, the system cannot remain in mid waters; ice formation may be deep enough to touch the sea bottom. A different design is then considered. The armour is now made of conical elements suspended to each other by for example chains. In addition to have transverse flexibility, the conical shape of the elements allows the armour to have an adjustable length. This is a critical property, as the distance from the turret to the seabed installation will vary relatively a lot. The riser will slide inside the armour, as its length will vary.

It is envisaged that offshore loading of oil in arctic ice conditions will require icebreaker assistance several months of the year. An alternative to offshore loading will be pipeline transport to shore, taking into account the low temperatures of the seawater and in the shore approach region. Furthermore, the ice conditions in a harbour may

necessitate production stops over longer periods should the storage capacity not be sufficient or should the pipeline not be connected to an onshore pipeline network.
If a stable oil product is prepared offshore, the remaining gas and unstable condensates (rich gas) have to be transported to shore for use, be used for fuel offshore or be injected in the reservoir for possible later production when or if a network of gas gathering lines is installed offshore.

The design of pipelines in the Arctic does, however, lead to challenges associated with trenching to avoid interaction and possible damages from ice ridges and/or icebergs. The status from an ongoing project to assess the necessary depth of pipeline trenching has recently been reported by Liferov et al. (2003).

Finally, it should be mentioned that the shore approach for pipelines in the Arctic represents a particular challenge, as the coast is susceptible to abrasion from freezing and melting soils. Experience with shore approaches on the European continent and to the rugged Norwegian coast is most relevant for the Arctic in case tunnels would be considered (Palmer and Gudmestad, 1999).

TRANSPORT OF THE PRODUCTS FROM AN OFFSHORE GAS FIELD

For an arctic offshore *gas field*, pipeline transport to shore of the gas and the unstable condensate will normally represent the most obvious solution. This will necessitate onshore treatment facilities of the rich gas to extract the condensate products whereby the sales gas (that is mainly the methanol) will be shipped to consumers through pipelines.

This solution will necessitate offshore loading of any oil and stable condensates offshore. The STL solution particularly aimed for deeper arctic waters with ice (Figure 4) will be ideally suited for this application. When a ridge passes a moored tanker, there are risks for parts from the keel or even the consolidated layer to hit the riser system. Anyway these impacts will not happen at any depth, but on the upper part of the riser. Thus a protection is needed only for the upper part of the riser. The armour can be made of cylindrical hollow elements suspended to each other. Due to the slack between two elements, the armour will be flexible, and the energy from the impact with an ice block will be absorbed in flexing of the armour.

As part of the different transport concepts a direct full well-stream to shore could also be considered, as is the case for the Snøhvit development offshore Finnmark. Here the full well-stream is transported 145 km to shore in a pipeline. This technology is applicable only if one can guarantee that hydrate plugs will not form in the pipeline, and therefore only if methanol or other inhibitors that dissolve possible hydrate plugs are injected into the well-stream at the wellhead. This is applicable only if the distance to shore is not “too long”. One should in this respect note that the technology is stretched to its present capability for the Snøhvit development, however, it is expected that future technology development will allow longer distances of full well-stream transport.

The use of this full well-stream technology in the Arctic will, furthermore, necessitate use of subsea wells, a technology that is not yet fully documented for use within an ice environment. One major problem is the possibility that one does not have access to the wells certain periods of the year to carry out maintenance or to stop production in case of problems with the equipment. Alternatively, for the case of a high gas to oil ratio, an offshore platform could merely act as a first stage separation platform, whereby the gas is dried and the water is taken out for easier multiphase transport to shore. It should be noted that this is the process solution for the Troll gas field that Statoil has operated for a number of years.

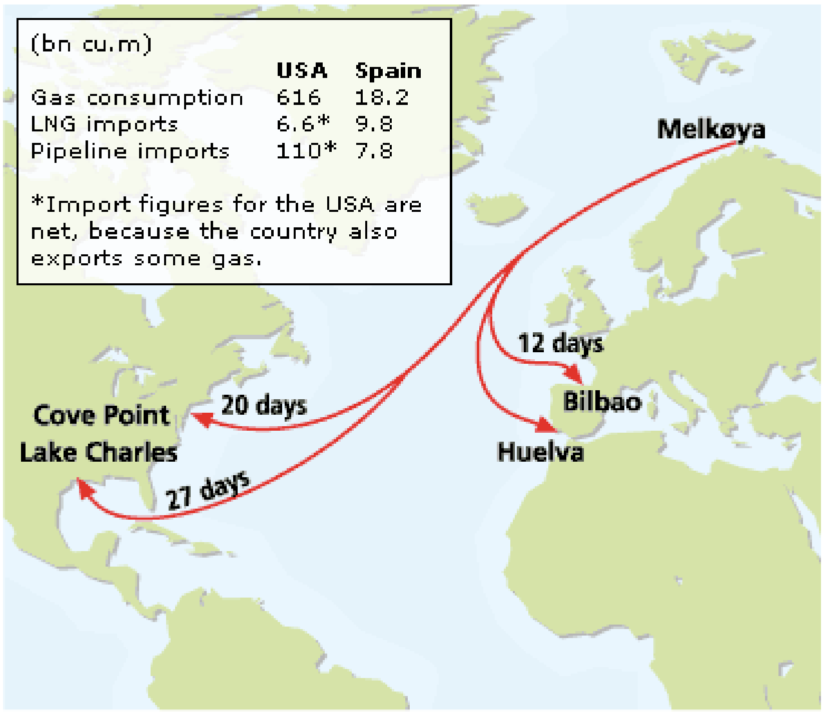

Fig. 4. Transport routes for LNG from the Melkøya LNG facilities

LONG DISTANCE TO MARKET

Even when the hydrocarbon products have been transported to shore, the distance from an arctic terminal to the market is large. Thus, the gas from the Snøhvit field will be processed into LNG (Liquefied natural gas) at facilities on Melkøya close to Hammerfest (Figure 4), rather than installing a pipeline to reach the European market.

An alternative technology that also could be considered is the transport of compressed gas in large "bottles" under high pressure without cooling the gas to LNG. The technology is, however, still under development.

For transport of oil products to the market, there is a growing concern that transport by tankers represents a potential environmental hazard. This will necessitate cooperation between countries, use of safe double hull vessels, strict adherence to appointed sailing routes and sailing procedures, and functioning emergency preparedness procedures. Particular emphasis may have to be put on weather forecasts and a reluctance to sail under the adverse weather conditions. Furthermore, warning procedures for transport of dangerous cargo and procedures allowing the countries to follow the tankers on radar when passing outside their territories must be agreed on. It will also be necessary to agree on procedures for seeking safe harbour. International cooperation to an extent not yet implemented in the maritime world is called for in this respect.

USE OF EXISTING FACILITIES AND POSSIBLE USE OF SUB SEA DEVELOPMENT SCHEMES

For field development in the Arctic an extended use of installations that are being installed is called for, in order to reduce investments and enhance the productivity of each installation. Like in the North Sea, the phasing of satellite field production into existing installations is expected to be very profitable. The first arctic offshore fields are in the process of being developed (Offshore Sakhalin and Pechora Sea), however, the planning for an optimal utilization of these production units is necessary. The prospect of using sub sea development solutions in ice-infested waters has to be studies and a research programme aiming at understanding how less capital extensive development schemes could be achieved under arctic conditions would be welcome. A suggestion of using fixed movable caisson platforms over subsea templates for drilling has been presented by professor Mirzoev (1999); a solution further detailed by Shafrova and Gudmestad (2003).

EFFICIENT PROJECT MANAGEMENT

The optimal way of executing development projects for the Arctic must emphasis effective project management. Planning tools are particularly important when it comes to taking the appropriate decisions in the different phases of the project (Figure 5) and when it comes to steering of the actual project execution. The assistance of an experienced operator used to deal with development of large offshore projects will help to ensure a successful project execution.

It is in this respect important that the investors gain confidence that the project design and fabrication phase as well as the marine operations and start up of the facilities will be executed efficiently within the agreed cost and time schedule. Figure 6 shows the economical effect on a typical offshore development project by a delay of one year.

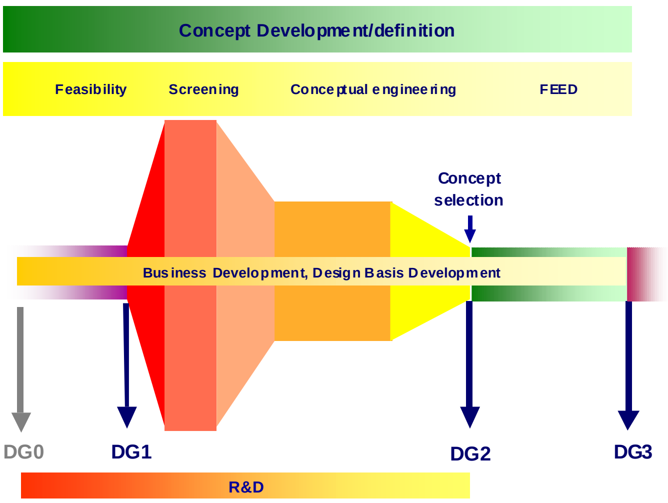

Fig. 5. The different early development phases of a project

Use of local goods and services will also be important in enhancing local industry, in particular for projects in Russia where it is thought possible to carry out construction work or buy equipment at very competitive rates.

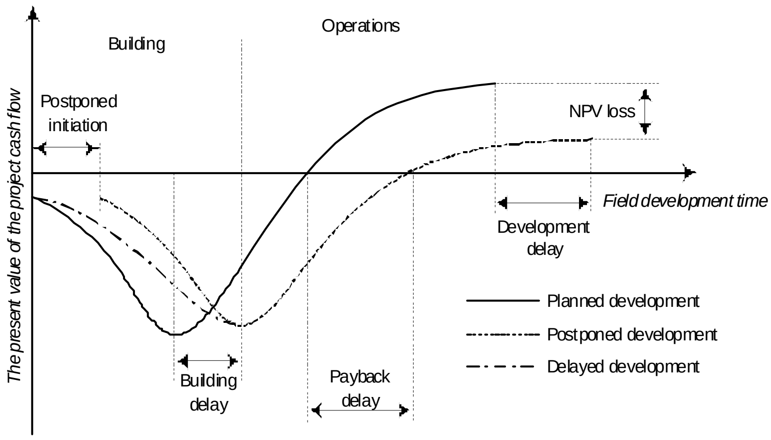

Fig. 6. Effects of a delay on the economic parameters of a project

CONCLUSIONS

For the development of arctic offshore hydrocarbon fields, it is extremely important to design the offshore production units to withstand the environmental forces from the arctic ice to ensure safe and environmental friendly operations. It is, however, also necessary to think in terms of optimal hydrocarbon process schemes to ensure that the economic benefits from the production be optimized and to optimize the recovery from the reservoir.

The selection of export and sales products from an offshore production unit will influence on the transport scheme, where we call for utmost care in design of arctic pipelines and/or offshore loading units. In this respect the STL is suggested to represent the best offshore loading alternative provided the water depth is sufficient for this technology.

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