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Design of Subsea storage tanks for Arctic conditions - heat treatment of materials

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Abstract

The Arctic region contains a plethora of recoverable hydrocarbon wealth in the form of oil and gas in existing conventional wells and other undiscovered fields. The main challenges faced in the Arctic region are both environmental and operational. Some environmental challenges are low ambient temperature, winterization, severity and unpredictability of the weather. However, the issue of multi-phase flow in the current operation coupled with the decline of the reservoir pressure are the major concerns in this gas field. In the early stages of field life, the reservoir pressure is sufficient to allow the natural flow from reservoir formation to surface without additional supporting compression. Unfortunately, the pressure naturally declines throughout the entire life cycle of the field. To achieve a better production profile in the arctic region the idea is to implement a Subsea processing concept employing a Subsea Storage Tank (SST) in order to maximize production from additional infield wells, introducing a novel step in this field development phase that will change the entire oil and gas industry especially for subsea processing field architecture. The

incorporation of SST in the subsea system will enhance the production rate as well as it avoids the transportation problems through pipe lines. By this work, the production rate is increased by 50% and decrease the oil spill accidents considerably.

Introduction

With arctic oil and gas exploration coming to be a new frontier in oil and gas exploration, there is need to bring in innovative ideas capable of confronting this challenge. Consequently, considering this challenge technically and commercially, engineering has got to strive to give solutions with objectives of minimizing cost of operation and improving reservoir performance [1]. Among these issues in the field of study, are multiphase flow, icing and polar low and this make production quite a serious problem for the industry. In multiphase flow, all the produced hydrocarbons are not separated into oil gas water and CO_2. Once multiphase flow reaches the refineries these hydrocarbons are processed by various treatment methods and the oil gas condensate water and CO_2 are separated and sent for exportation [2]. The separated carbon-di-oxide got injected back into the well to enhance the production recovery. This multiphase flow through the underwear pipelines have experienced many problems through the past two decades. The most common causes of pipeline incidents (35%) involve equipment failure. For example, pipelines are subject to external and internal corrosion, broken valves, failed gaskets, or a poor weld. Another 24% of pipeline incidents are due to rupture caused by excavation activities, when heavy equipment accidentally strikes a pipeline. Overall, pipeline incidents are most common in Texas, California, Oklahoma, and Louisiana, all states with considerable oil and gas industry[3]. The Arctic's marine ecosystems are particularly vulnerable to oil spills from blowouts, pipeline leaks or shipping accidents [4].

The proposed design has looked at the possibility of using an SST to eliminate the earlier mentioned existing issues associated with the field. This will ensure that condensate is separated from the crude oil by providing a storage solution and thereby providing among others, a good platform for field expansion and eliminate multiphase issue that has since characterized our field of study [5]. Condensate will be separated by a separation unit which will be stored in the SST while the gas can be conveyed through the existing export pipeline. The SST will be incorporated with a flexible bag which collects the condensate and as it expands, seawater in the tank is expelled until the bag is fully filled. After which the condensate is conveyed through a riser from the cap of the structure [6].

The aim of our project is to analyse the response of the SST in Arctic waters. The analysis extends to different case studies interpreting different scenarios. The scope of this project is

in developing and extending knowledge of heat transfer on SST which is vital for future development in new subsea field architecture. It may be able to change and expose the new concept in the Arctic region.

One of the recent innovations is the SST which is designed for storage and stabilisation of the liquid phase of production fluid on the seabed, the latter is then exported by shuttle tankers through export risers. The damage to this tank can cause an oil spill leakage and pollute the entire environment and ecology system in concession. There comes the novel concept of subsea storage system which can withstand iceberg impact and maintain the original properties are the key innovation for future Arctic oil and gas industry [7].

SST is the subsea storage equipment, a recent innovation by Kongsberg Oil and Gas Company (Fig. 1), which incorporates a flexible bag to contain the production liquid. It is a gravity-based storage tank that differs from conventional gravity storage systems by the flexible bag, this eliminates contact between sea-water and the stored fluid, thus eliminating the problems with emulsion layer and risk of bacterial growth. The bag is covered by a rigid structure in order to protect the damage of whole fluid containment and considered as the secondary protection containment [8]. To begin with, the external protection structure can be made with three types of material which are steel, GRP and concrete. Generally, steel material provides lighter dry weight with ease of fabrication in comparison with other materials though it requires good corrosion protection system and anchoring system during installation phase. The flexible storage bag is a recent innovation which is made with composite materials from combination of coated fabric and woven textile [9].

Section snippets

Conduction

Conduction is a phenomenon of heat exchange characterised by physical contact between the two entities, this contact allows the heat to flow from the warmer to the colder body, erasing the temperature gradient between the two entities. Convection is also characterised

by physical contact of the entities, one of which is a fluid. The fluid in contact with the surface is in constant movement as the internal difference of temperature of the fluid excites its particles providing kinetic energy to

Modelling and analysis

To complement the critical scenarios a material model has been considered. Proposed material model for ice is assumed to be isotropic and given a strain value to provide best realistic brittle behaviour.

Case A: Subsea Storage Tank wall composition performance

The steel considered in the analysis is characterised by a thermal conductivity coefficient of around 51.9W/mK, (Engineering toolbox), the breakout of the Subsea Storage Tank layers can be seen in Table 4.

Fig. 5 depicts the system's different materials, where the red area is the oil, the purple flexible bag and the light blue is either the steel or the concrete depending on the case. The pink area as well as the thin layer on top of the steel is water, this is because a very thin layer of

Case A: Subsea storage tank wall composition

The case of steel walls under an oil inlet at a temperature of 80°C provided the following diagrams as shown in Fig. 6. It can be seen that after a period of one day from the oil inlet in the Subsea Storage Tank, the temperature depletes of around 20°Celsius. The heat flux spreads along the steel walls, which keep a temperature equal to the external water. The temperature of the oil in the flexible bag spreads from a maximum of 61 °C in the core, till reaching around 25 °C at the flexible bag

Conclusions

The passive protective measure ensures a better heat exchanging behaviour compared to the simple system. The insulation of the Subsea Storage Tank is essential in order to keep the fluid over the wax deposition temperature, in order to avoid solid formations of paraffin in the whole structure. Possible solutions in order to limit the wax deposition are discussed and recognised to behave favourably, especially by the use of a multilayer barrier with preheating treatments of one or more layer of

CRediT authorship contribution statement

Arvind Kishor Tirumanur Shanmugavelu: Investigation, Writing – original draft. **R. Muraliraja:** Methodology, Writing – review & editing. **Ragavanantham Shanmugam:** Supervision, Formal analysis. **Mayur Pal Singh Pawar:** Conceptualization, Formal analysis. **Rajoo Vishwakarma:** Writing – review & editing. **Proshanta Sarkar:** Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References (15)

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Cold Reg. Sci. Technol. (2008)

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Cited by (1)

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