Crude Oil Subsea Storage System

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Kongsberg Oil & Gas Technologies is, through a Demo 2000 project, qualifying a Subsea Storage Unit (SSU) with support from Statoil, Lundin, Det Norske Oljeselskap and the Norwegian Research Council.

The SSU is characterized by using a flexible bag as oil / fluid storage. It's storage unit that differ from conventional gravity storage systems by use of a flexible bag, which eliminates contact between seawater and the stored fluid, thus eliminating the problems with emulsion layer and risk of bacteria growth. The bag is further covered by a protection structure, which accommodate the whole volume of the stored fluid thereby providing a second barrier should the bag rupture. There is free flow of seawater into the base of the protection structure and hence no needs to design against the water pressure. The top of the protection structure is designed such that the bag may be retracted separately from the storage tank if necessary for repair or replacement.

Different fields will have variable storage needs and the ability to size, combine and manifold multiple SSU's provides attractive flexibility. The number of SSU's can also be varied over the field life enabling subsea processing and production in arctic areas and also commercializing development of marginal oil field or tail end production.

The Subsea Storage System is intended for storage of stabilized crude oil at the seabed. The crude oil may be separated on the Topside platform or with Subsea processing and transported subsea through pipelines to the Subsea Storage Unit. The Subsea Storage Units will be discharged to a nearby shuttle tanker via a submerged offloading system or via topside.

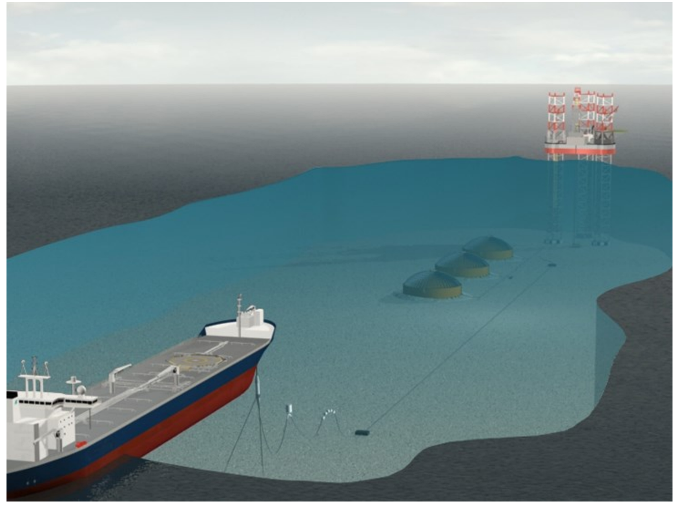

Figure 1 - Subsea Storage Unit configuration with topside processing

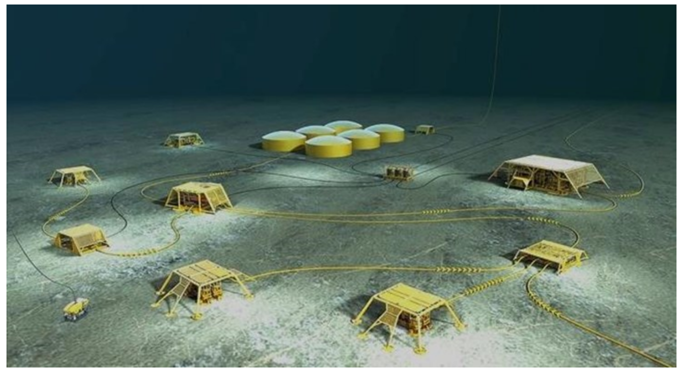

Figure 2 - Subsea Storage Unit configuration with subsea processing (Illustration courtesy of Statoil)

The Subsea Storage Unit - is a subsea storage unit that utilizes a flexible bag for oil/liquid storage. The bag is further covered by a protection structure, which accommodate the whole volume of the stored fluid and thereby also providing a second barrier should the bag rupture. At the base of the structure there are openings providing free flow of seawater into the structure and hence no need to design against the water pressure. The top of the protection structure is designed with a special hatch arrangement enabling bag retrieval or installation separately from the protection structure if necessary for repair or replacement.

The base case configuration and size of the SSU chosen is 25,000m3 (~158,000 barrels).

Two types of materials have been recognized as feasible for the 25,000m3 protection structure; steel and concrete. Both these materials are used for building large offshore and subsea structures.

Both steel and concrete has Concrete gives good insulation, corrosion protection and sufficient weight to accommodate a stable installation. As an example, for a 25,000 m3 size SSU, a concrete construction will have a wet weight of approx. 8,000 tons. The buoyancy from oil in a full tank will, due to difference of density between oil and water, be around 5,000 tons. Concrete construction represents a structure based on field proven technologies and it can be fabricated locally in an existing dock or a special purpose graving dock can be established.

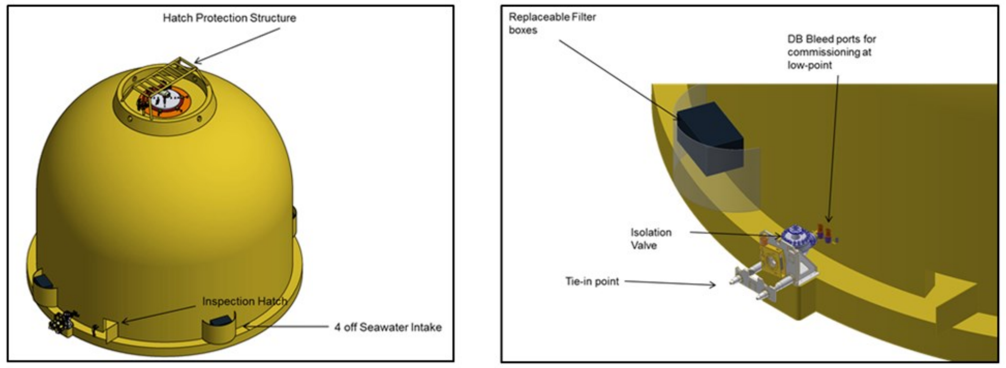

Figure 3 - SSU protection structure and tie-in point detail

Steel construction will be lighter than concrete. A steel construction for a 25,000 m3 size SSU will be in the range of 1-2000 tons wet weight and will hence be buoyant when filled with oil. To accommodate the positive buoyancy additional weights or pile anchoring is required for a stable seabed condition. Both corrosion protection and thermal insulation is required for the steel alternative. The amount of corrosion protection required is dependent on level of coating selected and may vary from application to application. Dependent on the characteristics of the specific crude oil additional insulation is required in order to meet requirements for wax temperature. Steel construction is based on proven technologies and can be fabricated in a dock or at an offshore yard. Choice of material will depend on customer preferences and soil properties for each specific installation.

The protective structure is designed to keep all oil inside without any leakage to the environment in case of a bag failure or rupture and with water intakes dimensioned to match oil discharging rate with necessary safety margins

Flexible bags for large subsea oil storage are a new concept but the use of flexible material exposed to oil, seawater, pressure and temperature is well known. Competent producers with proven production methods are available and have many years of experience. The main design criteria are the chemical resistance of the flexible bag material towards oil under influence of temperature and. Additional design criteria's are fatigue from bending and other wear and tear like friction between dome walls and bag.

Experienced producers are ready to produce the Flexible bag with the required quality and a life time of minimum 10 years.

Standard subsea crude oil storage systems are in general based on oil-water contact, where the reservoir is open to sea through a pipe system. The oil is replaced with water and vice-versa, when filling up or discharging from the reservoir.

One of the drawbacks with these storage systems is an ever growing emulsion layer comprising oil, seawater and chemicals. The chemicals are mainly added to the stored fluid in order to improve the separation of oil/seawater, reduce/avoid wax formation or reduce Microbiologically Induced Corrosion (MIC) caused by Sulfur Reducing Bacteria (SRB).

As the effect of the chemicals exhaust, more chemicals have to be added in order to keep the effect ongoing. Due to heavy restrictions regarding disposal of oily water or chemicals at sea, the emulsion layer becomes a problem. It is expensive to get rid of and takes up storage space in disfavour of the crude oil.

The emulsion layer also constitutes a risk of contaminating the discharged oil cargo. It only takes a relative small portion of the emulsion layer to raise the salt content of the crude oil cargo beyond acceptable specification, which will reduce its market price. Thus additional safety margins have to be added, which influence on the size of the layer and reduce available storage volume even more.

If not treated chemically, bacteriological growth occurs. Bacteria that 'consume' sulfur will form colonies that cling to the carbon steel walls and, during the 'digesting' process, produce acid which has a corrosive impact on the carbon steel.

There will also be a risk of transferring some of these bacteria to the shuttle tankers and further to the refineries, causing corrosion problems and clogged filters.

Eliminating the above mentioned threats by the SSU will enable the field-operators to secure their sale-spec. and fully optimize their storage requirement both volume- and cost wise.

The bag material is made of coated fabric with the core of wowen textile as the main load carrying structure, providing the required mechanical properties and strength. The coating on each side is designed to protect the textile and make it liquid proof. The total surface area of the bag is approximately 5 000 m2. The material is 1,5 – 2 mm thick and the total weight of the flexible bag is close to 10 tons.

Figure 4 - Rib boats, fuel tanks from Pennel & Filipo, membranes production from Continental

Figure 5 - Flexible bag design, production of bag, principle for vulcanizing sheets

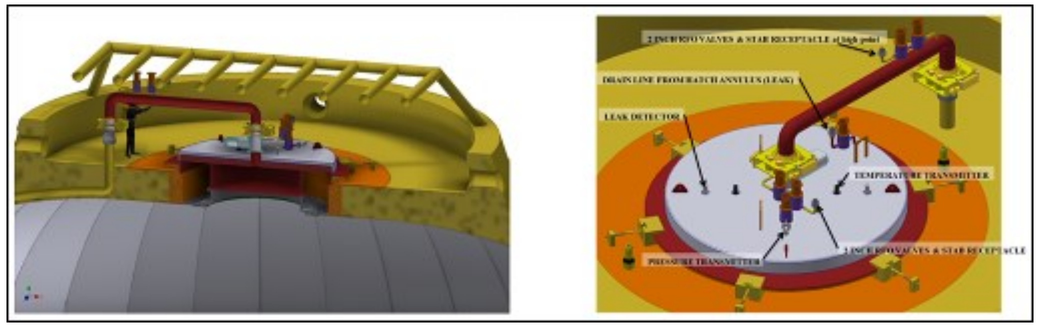

Figure 6 - SSU Hatch

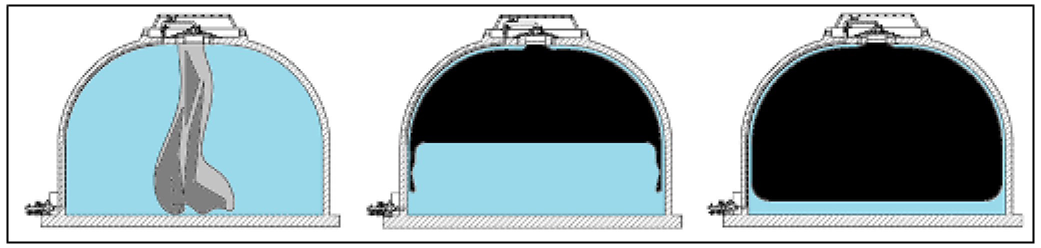

Figure 7 - Sequence for bag filling

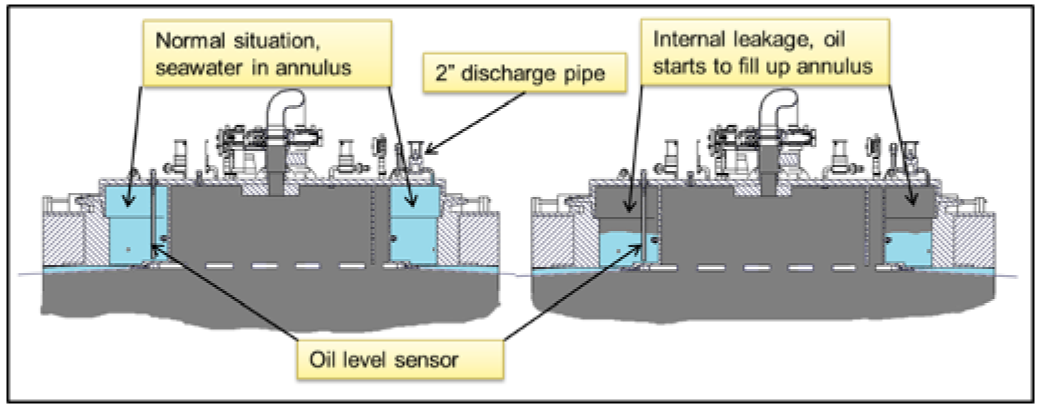

Figure 8 - Hatch detail, internal oil leakage recovery

Figure 4 illustrates different applications of this type of bag material.

Production of raw material and coated fabric are within normal production quantity and processes with good capacity. Joining or seeming the coated fabric sheets is a central part of the manufacturing. Each sheet will be cut to the right shape and slightly overlap the next sheet and the composition will form an overall approximate 3D surface and by the elasticity in the material it will easily fit to the perfect 3D shape in the dome.

Figure 5 illustrates the bag design and the production method for joining material sheets into final product.

The hatch arrangement on top of the protection is designed to provide full sealing and mechanical connection between the structure, bag and the environment. There is an integrated sealed connection between the flexible bag and the hatch, to prevent stored oil in the bag from entering the tank's annulus and/or the surrounding environment. The hatch is removable and installable by means of a driverless operation.

The protection structure can securely contain all the stored oil in case of a bag rupture. In the event of an accidental oil leak through the bag for whatever reason, there will be direct contact between oil and water, but no oil will reach the surrounding sea as the protection structure will hold the entire oil volume of a full SSU bag with safety margins. The oil will be discharged by the main pipe and any remaining oil outside the bag is discharged by a separate ROV operable connection at the top of the hatch.

The SSU system is operated and controlled by the field operator as a part of the normal field process operations.

Due to the density difference between oil and seawater the oil will always fill the bag from the top and move down in a horizontal level.

Different fields will have variable storage needs and the ability to size, combine and manifold multiple SSU's provides attractive flexibility. The number of SSU's can be matched to field life production and Tail end production can be optimized.

The SSU system is a natural and cost efficient alternative

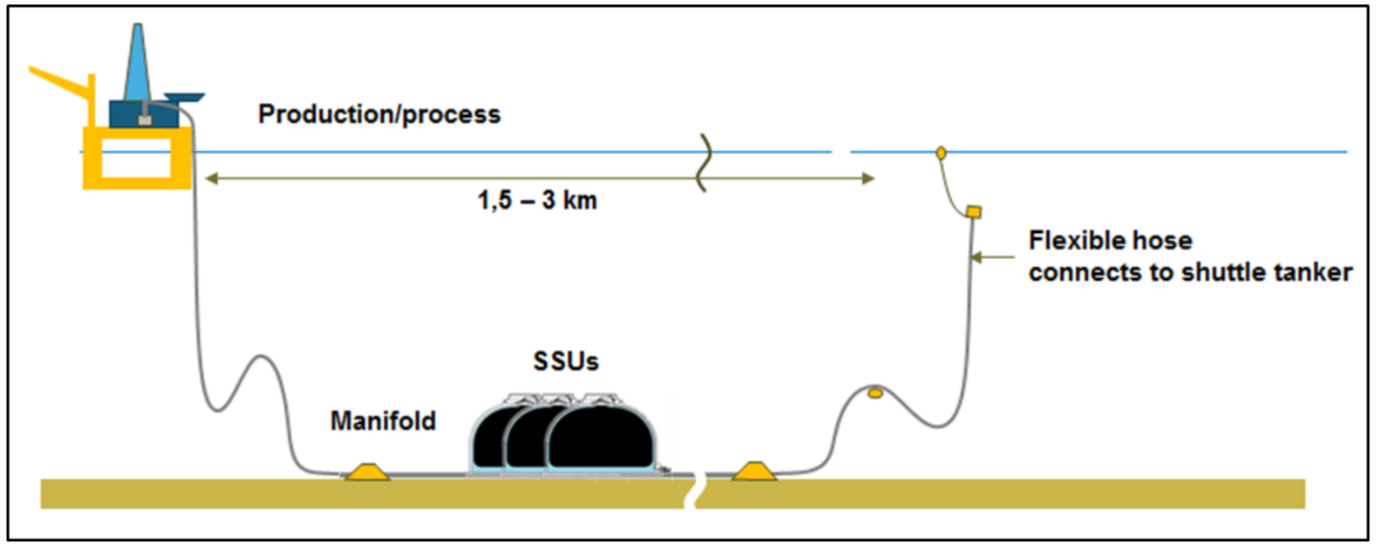

Figure 11 - SSU field layout

to a surface based Floating Storage and Offloading (FSO) vessel exposed to the full force of nature. For a field development scenario utilising SSU instead of a FSO vessel no separate personnel are required for the SSU and hence no crew change/helicopter transfers and other logistic issues. This provides valuable HSE benefits in addition to significantly reduced maintenance and running cost.

The flexibility and the cost savings the SSU technology offers may help commercialize development of marginal oil fields.

Figure 11 illustrates a typical field layout for an SSU application. The SSU's are connected with a topside facility with direct offloading to shuttle tanker.

The trend in the Oil and Gas Industry is more and more processing subsea and reduction of surface facilities. Future complete Subsea Field Developments could be developed with SSU's as seabed oil storage and export via shuttle tankers as an alternative to long pipelines. The SSU system could also be utilised for storage of chemicals and other operational liquids. The SSU provide the vision and ability to develop remote oil fields with a complete subsea solution and export via tankers.

There are several challenges to oil production in arctic areas. The SSU with its dual barrier protection philosophy provide the ability to store oil on the seabed under the ice and out of the way of icebergs and thereby enabling alternative development scenarios.

Torleif and guests on the Lectured dinner at Olivia, April 23 2014

Should you have any questions regarding SSU, please contact

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