In the last few years, several new offshore oil fields have been discovered. The current findings from Petrobras and other companies in the pre-salt province, located in the Brazilian continental shelf, suggest reserves of over 50 billion barrels of oil. Extracting the pre-salt oil is challenging and done increasingly with floating production storage and offloading units (FPSOs). Sulzer offers a variety of tailor-made pumps for FPSO applications.
**Floating oil production**

FPSO (floating production, storage, and offloading) is a floating system that produces oil from subsea reservoirs. Approximately 160 units are installed and in operation worldwide. Most FPSOs are ship-shaped and anchored (moored) by a turret. This kind of ship has been serving the offshore oil and gas industry for nearly 30 years. It provides economic advantages such as: faster development than on fixed platforms, reduced up-front investment, increased mobility (possibility of relocating the production to other fields), easier deeper field production, and lower abandonment costs than for fixed platforms.

In 2013, 46 new oil reserves were discovered, of which 14 are located in the pre-salt fields (e.g., Tartaruga Verde, E Mestiça, ES Deep Water, Carcará, Libra field). Petrobras intends to produce 4.2 million barrels per day by 2018, and 52% of this production will come from the pre-salt fields. It foresees an investment of USD 153.8 billion for exploration and production. Sulzer is a leading provider of pump solutions for FPSOs. Its success is based on innovative and customized pump designs that can cope with the severe conditions on the high seas. Sulzer develops and manufactures pumps for very demanding standards (e.g., NORSOK standards of the Norwegian petroleum industry, NFPA standards of the US National Fire Protection Association) to ensure safe, reliable, and high-availability operation. Sulzer produces the pumps according to customer specifications in several plants around the world: Brazil, UK, USA, Germany, India, and China. These plants can string test and run the pumps at full load in most applications (Fig. 1).

**Special requirements for water injection**

In addition to meeting standard requirements (like ISO 13709/API 610), FPSO pumps have to fulfill some additional directives for operating in severe conditions. Critical sea conditions may arise, resulting in large pitch and roll motion amplitudes (Fig. 2). Sulzer designs the pumps to ensure safe and reliable operation. For example, the water injection pumps that Sulzer manufactures for FPSOs are designed, manufactured, tested, and completely packaged with stiff baseplates, API 671 couplings and antivibration mountings. Furthermore, they have special piping, lubrication, and instrumentation systems according to ISO 10438 (API 614). These high-pressure pumps are used to inject seawater into the oil reservoir at subsea level to stimulate production. The water injection prevents low pressure in the reservoir and sweeps or displaces oil towards a well up to the FPSO’s tank. Injected seawater replaces the oil that has been taken and thereby maintains the production rate and the pressure over the long term.

The required flow for water injection depends on the field. For example, the development for the Brazilian pre-salt field is expected to inject 1500 to 3000 m³/h of seawater and sustain pressure up to 350 bar. The number of water injection pumps working in parallel in an FPSO depends on the design concept of each oil rig. Because of the variability of operation conditions and because it aims to meet all market demands, Sulzer has various pump types in its portfolio, including GSG,
Panorama

The pitch and roll conditions on FPSO units are challenging.

1 At the Jundiai test bed, Sulzer can perform string tests at full load.

MSD, HPcp, and CP pumps (Fig. 3). All existing water injection applications are covered by these pump types because the pumps are flexible in terms of speed, number of stages, pressure design, and variety of hydraulics with high efficiency.

New pumps for seawater lifting

Other typical products for FPSOs are seawater lift pumps. These pump types are designed and applied for lifting the seawater to the production processes, such as cooling systems, firewater, and injection. There are three types of seawater lift pumps:

- Dry-mounted pumps taking suction from the sea chest–BB1 (between bearings) vertical inside the hull
- Vertical lineshaft pumps
- Vertical pumps with submersible drivers inside the caisson

The most recently developed Sulzer product for lifting is the SJS vertical pump. Its main characteristic is a submersible driver. This provides a more cost effective solution than the BB1 vertical and lineshaft pump type because of its compact design. Recently, Petrobras purchased 30 SJS pumps from 100 to 1100 kW for their FPSOs from Sulzer (Fig. 4).

Cargo pumps for varying conditions

Cargo, oil-offloading, and oil transportation pumps also have specific designs, and most of the applications require engineered solutions. The purpose of these pumps is to export crude oil from tankers or pipelines to shore. Pumps have to deal with a variety of crude oil properties around the world (low and high viscosities and temperatures, sand, chlorides, hydrogen sulfide contents, etc.). The operating conditions vary as well (offloading times of 24 hours, flows from 20,000 up to 40,000 barrels/h, and intervals of 7 to 10 days between each offloading). Sulzer pumps are designed to cope with these challenges and offer high performance, reliability, availability, and easy maintenance on board. Figure 5 shows the HPDMV cargo pumps that Sulzer delivered for Petrobras.
Critical firewater pumps
Safety is a critical issue for all platforms and FPSOs. The firewater pumps, associated drives, and their respective automation systems are integral parts of the safety systems. The firewater pumps and their accessories must be ready to start up immediately and run up to full load as soon as the fire alarm is triggered. They must remain in continuous operation under the most severe and difficult conditions. There are many designs and solutions available for the platforms and FPSO firefighting applications. Oil companies like Petrobras and Total normally define the firefighting units considering vertical lift pumps driven by inside caisson hydraulic motors and containerized diesel engines with OH2 (overhung) booster pumps. Other customers like oil and gas engineering, procurement, and construction companies use to specify dry OH2 or BB1 pumps driven by hydraulic motors and skidded diesel engines with OH2 booster pumps. All the concepts must comply with NFPA 20 standards as well as further regulations of classification authorities (ABS, DNV, BV, and others) and specific directives (CE mark, SOLAS etc.).

Since this product line is of vital importance to the safe operation of platforms and FPSOs, Sulzer has invested considerable resources over time into the continuous improvement of its firewater product portfolio. One of the latest products developed by Sulzer is the vertical pump (BK'n type) hydraulic-driven solution. It includes the following components: containerized diesel engine with its respective gas exhaust, booster pump (ZE type), hydraulic power unit, diesel reservoir, engine-starting system, batteries, redundant battery charger, ventilation, fire detector, smoke detector, and gas detector, instrumentation, and control panel for 18 hours of continuous operation. All of the components are located inside of the container, which is designed to the insulation standards J 120 and H 120.

All Sulzer firefighting systems are designed, manufactured, and full-load-string tested in the factory. They are also tested on site according to the Classification Society regulations for final acceptance.

New test setup for pre-salt reserves
The number of platforms and FPSOs being constructed to operate far from the shore in deep fields is increasing. Operators require that all pumps and their accessories present higher reliability and MTBF (mean time between failures) and lower operational costs. These criteria are always taken into account during the design and manufacturing phases. However, one of the most important points to consider is the testing before dispatching the equipment to the site. 3 Sulzer’s water injection pumps for FPSOs are specifically tailored for use in severe conditions on the high seas (top: GSG www.sulzer.com/GSG-pump, middle: CP www.sulzer.com/CP-pump, bottom: MSD www.sulzer.com/MSD-pump).
Once more, Sulzer has invested in test beds over the years, increasing its capability to carry out the performance tests at full speed as well as complete string tests to ensure safe operation on site. Sulzer’s pump facility in Jundiaí, Brazil, spent recently more than USD 4 million for a new power substation (128 MV) to be able to test pumps up to 15 MW. This new setup allowed Sulzer to carry out full water injection pump string testing for the central pre-salt reserve oil fields recently discovered by Petrobras in the southern part of Rio de Janeiro and north of São Paulo State in Brazil. The tests at full load ensured smooth commissioning and operation on site.

Orders received and successfully installed projects
Sulzer has a history of successful installations on a significant number of FPSOs produced by MODEC, Hyundai Heavy Industries, DSME Bumi Armada, Petrobras, and other oil companies around the world. Recently, Sulzer was awarded contracts to supply 6.0 MW GSG water injection pumps to Petrobras Cessão Onerosa, 5.8 MW GSG water injection pumps to the Modec Tupi Field, and SJS seawater lift pumps with submersible electric motors for six FPSOs to Petrobras.

Another successful product—Diesel Hydraulic Firefighting System—is being manufactured and delivered to Petrobras FPSOs. Sulzer is supplying 28 complete containerized systems to the Cessão Onerosa and Replicantes projects. Sulzer has also received a recent new order for four special containerized systems for the Egina field to Samsung Heavy Industries, whose FPSO will be operated by Total in Nigeria on Africa’s western coast.

These orders demonstrate that Sulzer is a recognized player for reliable, safe, and efficient pumping solutions for FPSO applications worldwide.

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