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Screw pumps move heavy California offshore crude effectively

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Multiple-screw pumps are ideally suited for transporting and processing heavy crude and emulsions. The pumps have high-pressure capability and excellent operating efficiencies.

Minimal space for treating equipment on a platform makes pumping heavy crude from offshore fields difficult. Water is difficult to separate from heavy crude and heavy crude also has a tendency to retain sediments/solids.

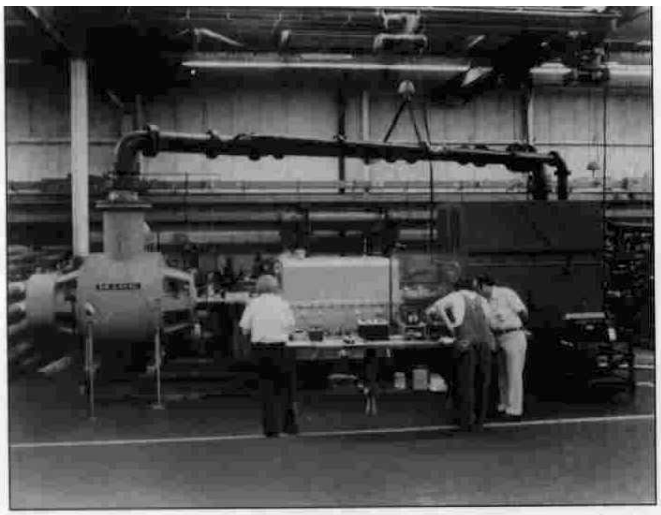
Original development

Exxon Corp.'s Santa Barbara channel operation, offshore California, is an example of a screw-pump installation.

In the early 1980s, Exxon began producing from the eastern part of the offshore Hondo field. Oil was gathered at Platform Hondo and sent to the Exxon Santa Ynez, formally the Exxon Newcastle, a permanently moored, 50,000 dwt tanker modified to process and treat 40,000 b/d (265 cu m/hr) of heavy crude oil. This offshore storage and treatment facility (OS&T) had 466,000 bbl of storage capacity, of which 234,000 bbl was dedicated to crude oil. Equipment on the vessel processed produced gas and water.

A shuttle tanker, the Exxon Jamestown (40,000 dwt with a capacity of 240,000 bbl) transported the heavy crude oil, 17.4° API, from the OS&T to coastal California facilities for further treatment and refining.

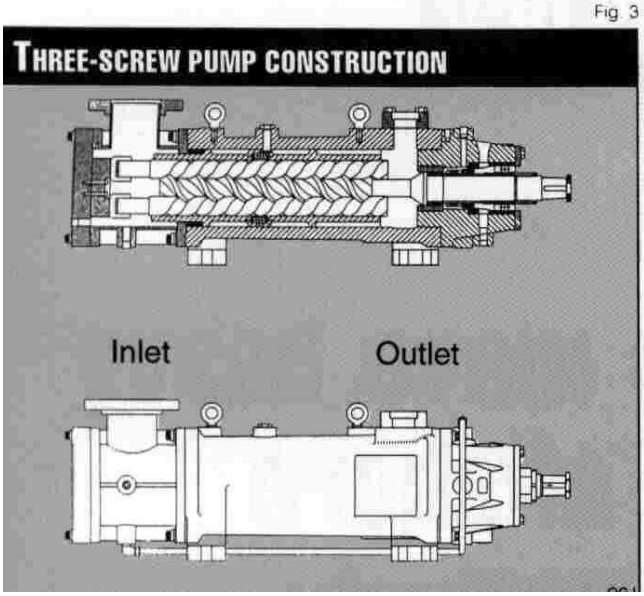
The main cargo pumps aboard the OS&T were double suction, horizontal twin-screw pumps with 15 3/4-in.

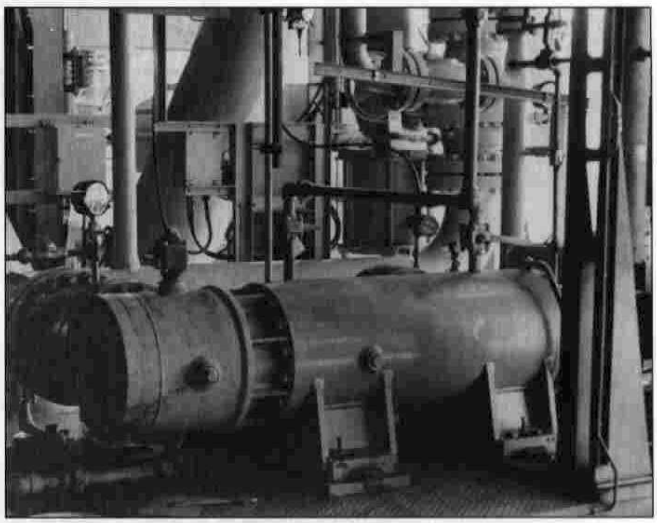


One of the main cargo pumps for the Exxon Newcastle is shown undergoing shop tests (Fig. 1).

Expansion of the Hondo field development included instal lation of the Harmony platform (Fig. 2).

Fig. 3





The screw pump, as installed offshore, has a capacity to deliver 27,500 b/d (Fig. 4).

(400 mm) diameter screws. These were the largest screw pumps ever built at the time. Each of the four pumps was driven through a fluid coupling by a 1,000 hp (745 kw) electric motor.

Fig. 1 shows the pump train on shop tests before shipment. These pumps operate over a speed range of 200-1,200 rpm, delivering up to 189,000 b/d (5,500 gpm) at a discharge pressure of 155 psig (10.7 bar). Design viscosity range was 8,000 SSU (1,726 cSt).

The pump's four $5\frac{1}{2}$-in. mechanical seals exclude cargo, crude oil emulsion, from the external timing gears and antifriction bearings. The replaceable pump liners were machined from ductile Ni-resist (high-nickel cast iron) castings. Shafting was of 17-4 PH (precipitation hardened) stainless steel while the pumping screws were a 400 series stainless steel. An integral overpressure relief valve was built into the pump casing.

The Jamestown has three similar versions of this twin-screw pump. The material and the flow and pressure capability are essentially the same as the OS&T cargo screw pumps. The pumps, installed in a pump room, are directly driven through bulkhead shafting by steam turbines in the ship's engine room.

Field expansion

Because limited OS&T processing capacity restricted development and production from the western part of the Hondo and the Pescado fields, Exxon installed additional platforms and a pipeline to shore.

The offshore portion of this expansion included two production platforms: Harmony (Fig. 2), for western Hondo in 1,075 ft (330 m) of water and Heritage for Pescado in 1,200 ft of water. Both platforms are in the Santa Barbara channel between Point Conception and Santa Barbara.

Platform start-up routines were initiated last November and in December pumping of the crude oil emulsion through the pipeline began. After the platforms and pipeline were commissioned, the OS&T and shuttle tanker were no longer needed and were released.

Each platform has three, eight-stage, three-screw, shipping pumps to move the crude oil/water emulsion through the pipeline to the Las Flores canyon onshore facilities for further separation and processing.

The pumps are powered through flexible disk spacer couplings by 800 hp (600 kw), 1,200 rpm, 4,000 v, 60 hz single-speed electric motors. Each pump delivers 800 gpm (27,500 bid) of heavy crude oil and water emulsion having a vapor pressure of 29.7 psia at a design discharge pressure of 1,190 psig.

Maximum system pressure is 1,430 psig. The emulsion has a viscosity range of 1,370-1,610 SSU over the pumping temperature range of 120-127° F. Pump system inlet pressure ranges from 18 to 83 psig.

At design discharge pressure, 1,190 psig and 1,610 SSU, these pumps operate at an overall pump efficiency over 83%.

Fig. 3 illustrates pump construction and Fig. 4 shows the pump as built and installed. Note that both the inlet and discharge port are oriented on the same side.

Pump casings and heads are carbon steel. This allows the discharge ports to be oriented to suit the platforms' space restrictions. The shaft seal is a positive-drive mechanical type in a tandem arrangement to API Seal Plan 52 and includes a seal pot to minimize the chance of hydrocarbon leaks to the atmosphere.

Running faces are carbon on silicon carbide, static seals are

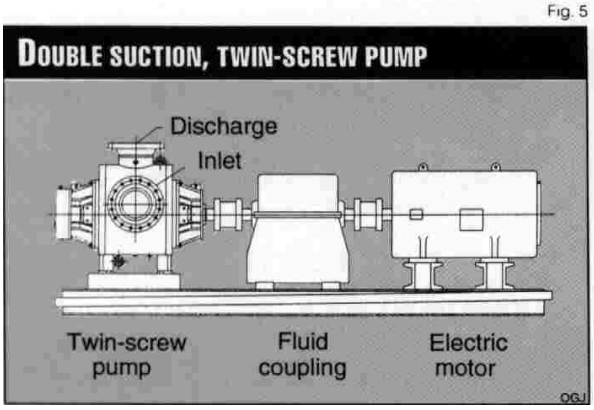
Viton, and metallic parts are stainless steel. The external antifriction bearing is grease lubricated and used to position the pump shaft for proper mechanical seal operation as well as to absorb minor axial loading from inlet pressure variations.

The pumping rotor set is an alloy steel that has been gas nitride case hardened and profile thread ground, much like high grade, heavy-duty gearing. This process results in rotor surfaces with a hardness of about 55 Rc (Rockwell C) for durability and closely held tolerances for optimum performance. Replaceable bimetallc liners allow overhaul of the pump while in place. Instrumentation includes velocity-type vibration sensors at both motor bearings and the pump bearing.

A Jan. 1, 1994, analysis of produced fluid from the two platforms was as follows:

- °API gravity, dry basis: 14.6 Harmony, 17.2 Heritage
- Density dry, kg/l.: 0.97 Harmony, 0.95 Heritage
- H_20 by volume, %: 14.8 Harmony, 1.1 Heritage
- Sulfur by wt %: 3.9 Harmony, 5.4 Heritage.

Fig. 5



The produced crude is degassed in separators, and free water is knocked out before entering the serge tanks connected to the suction of the platform screw pumps.

The Harmony and Heritage platforms are 7 miles apart. The Heritage emulsion is pumped 7 miles before joining flow from Harmony for an additional 11 miles to the onshore facility. The subsea pipeline has a 20-in. diameter.

Offshore Facility

The onshore facility for the Santa Ynez Unit expansion is in Las Flores Canyon, about 2 miles inland from the coast and 10 miles west of Goleta. Site elevation is 270 ft. All equipment at the site is designed for a UBC (Uniform Building Code) Zone 4 earthquake classification.

The crude processing design capacity is 100,000 b/d, expandable to 140,000 b/d. By 2000, projected operating rate is expected to be 90,000 b/d.

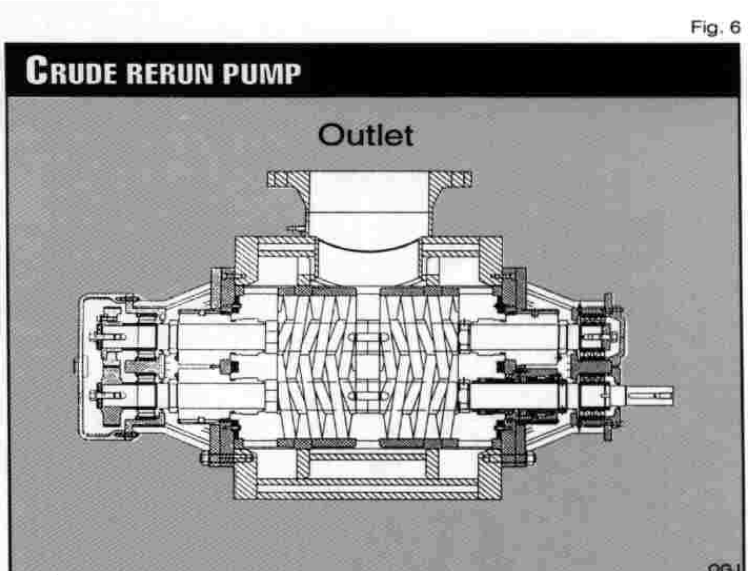
Water treatment capacity is 90,000 b/d. Treated water is piped back to Platform Harmony for disposal. The site's two tanks can store 540,000 bbl.

The crude rerun pumps in this onshore facility are double-suction, twin-screw design. Pump construction is illustrated in Fig. 6.

Screw pumps were selected because of the high-viscosity crude oil. These pumps operate at discharge pressures up to 240 psig over a viscosity range of 30-54,000 SSU, and a gravity range of 7.2-22.3° API.

Maximum flow rate is 1,400 gpm (48,000 bid) for each of the two pumps. Rated system inlet pressure to the pumps is 6.6 psig with an oil temperature range of 60-100° F.

Fig. 6



One specified operating point required these pumps to handle 100% water at the rated discharge pressure of 224.6 psig.

Explosion-proof, constant-speed electric motors (600 hp, 1,200 rpm, and 4,000 v) drive each pump. The main pumping unit includes a fluid coupling between the fixed-speed electric motor and the twin-screw pump (Fig. 5). The 19 ½ ft long package weighs just under 15 tons. The standby package without the fluid coupling is 13 1/2 ft long and weighs 10 tons.

To accommodate the crude oil under a worst-case, high-viscosity, cold-oil condition, the fluid coupling allows a pump speed variation of 227-1,136 rpm. The standby pump and motor are identical but without the flu-id coupling.

All shaft-to-shaft couplings between equipment are flexible disk, nonlubricated, limited end float, spacer designs with 307 stainless steel disks. The couplings are guarded with hinged, spark-resistant OSHA coupling guards. Baseplates are fitted with sloped drip rims. At each end of the pump, pump instrumentation includes two velocity-type vibration sensors at the pump bearing housings.

The pump cases are carbon steel plate and incorporate an integral 150 psig steam jacket for heating the pump under the most severe viscosity conditions. The replaceable liner is machined from cast ductile Ni-resist, a high nickel material that has good corrosion and erosion resistance.

Pump shafts are of 174 PH stainless steel. The replaceable 10^1/2-in. diameter pumping screws are manufactured from 431 stainless steel. The 3^1/2-in. mechanical shaft seals are tandem, balanced 316 stainless steel bellows type in a cartridge arrangement. The rotating faces are silicon carbide and the stationary faces are antimony impregnated carbon. Elastomers are Viton.

Each end of each pump has an API plan 52 seal pot system. The 316 stainless steel pots circulate a 50:50 mixture of propylene glycol and water through the tandem mechanical seals for seal cooling and to exclude petroleum emissions from the pumps. The pots include cooling coils. Each pot is supplied with 4 gpm of water.

The fluid coupling incorporates an explosion proof electric actuator

responding to a 4-20 ma control signal that causes the mechanical control linkage to change the coupling speed ratio. The fluid coupling also contains a magnetic tachometer pickup that sends an output shaft speed signal from a 72-tooth gear to the control room.

An ASME code, tube type, two pass, removable bundle, water-to-oil heat exchanger is incorporated with the fluid drive for cooling the circuit oil with 65 gpm of water. AH oil and water piping is 304L stainless steel.

The onshore processing plant preheats crude/water emulsion before sending it to a knockout vessel. Further separation is done with electrostatic fields, additional heat, and chemical additives. Sulfur is removed from the stream before the processed and heated crude oil enters All American Pipeline Co. Inc.'s pipeline.

The Author

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