Liquids Pipeline Report

Screw Pumps Provide High Efficiency In Transport Of Orinoco Bitumen

All pumps were fully tested and inspected at the factory before shipping to the job site. A single pump-motor package weighs nine tons.

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One of the world's largest known deposits of extra heavy hydrocarbons and natural bitumen is located in the Orinoco River basin of eastern Venezuela Production and transportation of an emulsion of bitumen and water is one of the major projects being directed by Petroleos de Venezuela S.A. (PDVSA). This emulsion is used for fuel for steam power generating plants in the U.S., United Kingdom, Canada, China, and Japan. A number of other European, Latin America, and Pacific Rim countries also are evaluating possible conversions of their plants to this fuel. Bitumenes Orinoco, S.A. (BITOR), a PDVSA affiliate, manages all production, distribution, and marketing of the bitumen-water emulsion.

Properties of Bitumen

Orinoco bitumen has a gravity ranging from 7.5 to 9.5 API (density of 1.003 to 1.018 grams/cu. cm.) and a viscosity of 1.5 million Saybolt Seconds Universal (SSU) at 77° F. (350,000 centipoises at 25° C.). While it is possible to pump liquids with this extremely high viscosity, it is economically impractical since enormous energy levels are required to overcome pipe line friction over required distances.

Intevep S.A., the research branch of PDVSA, has developed a technology which combines approximately 30% water and 70% bitumen with proprietary additives to form a stable emulsion which can be pipelined, tankered, tank farm stored, and burned. Prior to emulsification with water and suffactants, the bitumen is degassed, dehydrated, and desalted. The emulsion is called Orimulsion and is a registered trademark of BITOR.

Orimulsion is non Newtonian and exhibits an apparent viscosity change with change in shear rate and time at a given shear rate, as well as temperature. Bitumen droplet size distribution and weight percent also affects apparent viscosity. As formulated, Orimulsion approximates the apparent viscosity characteristics shown in Table 1.

The emulsion has a pour point of 5° C. (41° F.) and a flash point of 122° C. (250° F.) minimum. Sulfur content is 3% by weight.

Production of Orimulsion

Orimulsion is produced in the MPE-1 (Modulo de Produccion y Emulsificacion) plant in Morichal, Cerro Negro sector, in the state of onagas. Current capacity is 5 million metric tons/yr. and an existing 70 km. (43 mile), 24-in. pipeline transports it to Punta Cuchillo terminal, Bolivar state, on the Orinoco River. This is a relatively shallow water facility and is a much longer ocean

Reprinted from **Pipeline & Gas Journal**, March 1995

TABLE 1: PROPERTIES OF ORIMULSION

Temperature, °F. (° C.)	41 (5)	86 (30)	122 (50)	158 (70)
Shear Rate, 1/s	20	20	100	100
Viscosity, SSU	5100	3250	2100	1160
Viscosity, cps	1100	700	450	250

TABLE 2: PUMP COMPARISONS

Pump Type	Delivered HP	Efficiency, %	Required HP	Excess HP
Centrifugal	790	32	2469	1679
Centrifugal	790	60	1317	527
Screw	790	75	1053	0

shipping route to the northern hemisphere than a Caribbean Sea-based terminal. However, some 2 million tons/yr. are shipped via this route. Prime movers, which have been used for many years, for this facility are multiple screw pumps.

A new, 300 km. (186 mile) pipeline system extending from MPE-1 to an offshore tanker loading facility near Puerto La Cruz was slated for startup late last year. By the year 2001, plans call for 20 million tons/yr. of Orimulsion to be flowing from MPE-1, 2, 3, and 4 to Patio de Tanques de Oficina (PTO) near San Tome. PTO presently has three tanks with total storage capacity of one million bbls.

From PTO, a recently completed 56 km. (35 *miles),* 24-in. buried pipeline followed by 148 km. (90 miles) of 36-in. pipeline terminates at Jose on the Caribbean coast where another four tanks can store up to one million bbls. From this tank farm, two 36-in. subsea pipelines deliver Orimulsion to a marine loading buoy located 8 km. (5 miles) offshore.

Pump Selection

Choices for pump selections were reciprocating, centrifugal, or rotary screw. Reciprocating pumps were excluded early in the evaluation process due to cost, availability of sizes, and, significantly, high rates of shear that would be imposed on the Orimulsion during pumping. Since the emulsion is shear sensitive, minimizing its exposure helps to ensure its stability and viscosity predictability.

Centrifugal pumps, also known to be somewhat high in shear production, were evaluated since their initial cost usually is reasonable. Since the specific gravity of Orimulsion at pipeline pumping temperature was 1.000 (same as water), available engineering data were used from Hydraulic Institute Standards on correction of centrifugal pump performance on water to the viscous condition of Orimulsion.

While these correction factors were empirically generated for Newtonian viscous liquids (liquids which exhibit negligible viscosity change when sheared), the data were considered as adequate for initial evaluation. At a worst case Newtonian condition of 4,500 SSU (970 centistokes), the viscous efficiency correction factor was approximately 0.40. Assuming a water efficiency (31 SSU or 1.0 centistoke) of 80%, this would result in a centrifugal pump operating efficiency of only 32%. Even at a low end viscosity, further reduced under shear to 1,000 SSU (215 centistokes), the viscous efficiency correction factor of 0.75 would still result in a centrifugal pump efficiency of only 60% under the most favorable conditions.

Each pump would deliver the hydraulic equivalent of 790 hp into the pipeline. Table 2 compares efficiency and power requirements of the three choices on a per pump basis. Since plans called for operating two pumps on a nearly continuous, 24 hr./day schedule, the best case excess power consumption would have been 3.337 million Kilowatt-Hrs. (KWH)/ yr. and the worst case, in excess of 10 million KWH/yr.

Clearly, substantial energy savings was realized by using rotary screw pumps. Ancillary savings were realized in the size of starters and power cable runs required with this type of pump. Also, larger motors were necessary with centrifugal pumps.

Pumping Operations

Operated by Corpoven, S.A., a PDVSA affiliate, the three pipeline pumps at PTO near San Tome, 100 km. (63 miles) north of the Orinoco River, are Warren design, rotary, two screw, positive displacement types. They have timing gears and bearings external to the pumpage and separately lubricated. Each pump has a rated capacity of 2,552 gpm (87,500 bpd or 580 cu. meters/hr.) at a differential pressure of 531 psi and a pumping viscosity range of 1,000 to 4,500 SSU (215-970 centistokes). Net positive suction head available to these pumps is only 10 ft. of 1.0049 specific gravity Orimulsion. Pumping temperature is nominally 77° F. (25° C.) Pump casings are cast alloy steel and their screw bores are coated with industrial hard chrome and ground to a finished thickness of 0.010-0.012 in. The pumps are driven through guarded flexible spacer couplings by 4,000 volt, 60 Hz, 3-phase, 1,250 hp induction electric motors at 1,200 rpm. Direct drive avoids the need for speed reduction equipment which would be required if reciprocating pumps had been used. A spacer coupling allows removal of pump internals for service without disconnecting or disturbing pump-motor alignment since neither pump nor motor need be moved.

An overall efficiency of 78-82% at rated conditions is achieved with a volummetric efficiency of 94%. Relief valve set point is 576 psig where the pump power draw is 1,146 hp. The PTO pumping station is at an altitude of 1,000 if. which results in an atmospheric pressure of 14.2 psi. Pumps take suction from buffer tank storage (three tanks holding one million bbls. of Orimulsion). Units can be operated singly or two simultaneously with the third unit acting as a standby. Pump shaft seals are single, positive drive, multispring mechanical design with a solid tungsten carbide rotating face running against a carbon stationary face.

The pump seal's metallic parts are made from stainless steel and o-rings are of Viton. Stainless steel seal pots, with level detection, are used to maximize seal life expectancy. Antifriction hearings and nitride case-hardened herringbone timing gears are force-lubricated by a small oil pump which is driven from one of the two screw pump shafts. Lubricating oil is circulated through an air-to-oil heat exchanger and filter before delivery to the bearings and timing gear set. All of the lube oil system reservoir, piping, and tubing are made of

stainless steel and integrated into the skid with a pump and electric motor.

All of the pumps are equipped with remote temperature detectors for bearing temperature monitoring and proximity probes are installed in each bearing bracket to monitor vibration. Low level alarm switches are installed in both bearing housings and lubricating oil
tank. Lube oil flow and temperature switches also are present to detect possible problems which c6uld arise from a lack of lubrication. All three pumps were fully tested at the factory prior to shipment to the job site. A pump-motor package weighs 9 tons.

Fifteen other two screw pumps are used in the Jose terminal complex. These have the same casing size and basic design as the PTO pumps. Each is rated at 2,917 gpm delivery rates at a pressure of 275 psi. Each is driven
by a 4,000 volt, 60 Hz., 3-phase, 800 hp induction motor. Temperature and vibration sensing, lubrication, seals, and other features are essentially the same as the PTO installation.

Rotary screw pumps are the primary prime movers of crude oil in Venezuela mainly because of the heavier, higher viscosity, high gravity crude oil and the efficiency, small footprint, and non-pulsating flow characteristics delivered by this type of pump. Also, screw pumps are inherently low shear equipment even when operating at relatively high speed. Some screw pumps are being used in power plants that are fueled by Orimulsion. In this application, they serve as pipeline and transfer services, as well as, main burner pumps. No difficulties in operations have been experienced in transport-mg this type of fuel with this type of pumps. **P&GJ**