Heavy Crude Oil Transfer Using Twin-Screw Pumps – Applications in Sudan and South America

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ABSTRACT

It is not only since the Canadian heavy oil resources have been declared economical that in many other countries around the world this kind of hydrocarbons have been produced for a long time. Among these are Argentina and Venezuela as well as Sudan. Heavy oil has been defined to have a dynamic viscosity of more than 10 cP or less than 22.3 ° API, and a high specific gravity (>0.92 kg/m³). In addition there is ultra heavy oil (or bitumen) with a very high viscosity (> 100 cP) or less than 10° API respectively. Further to these unfavourable characteristics for pumping, there may not only be a considerable content of paraffin and wax, but also solids and some gas. This all requires certain additional measures in regard to pumping process and pump selection.

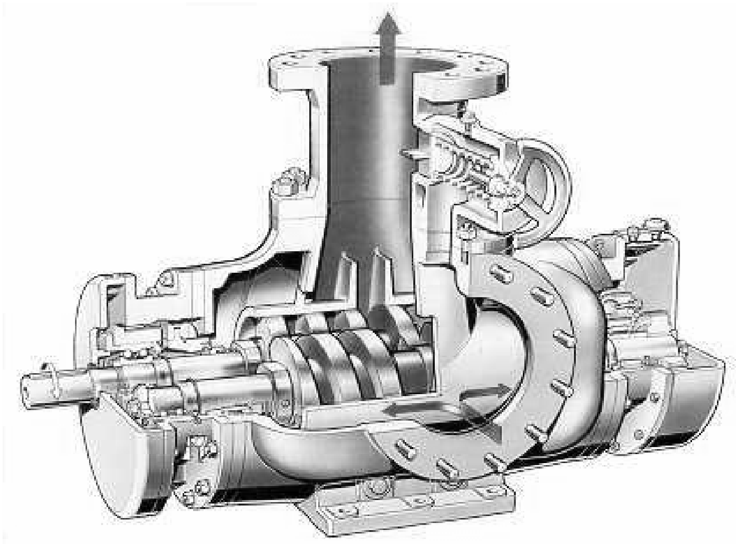
For several decades positive displacement pumps have a proven and excellent track record in such services with those using the twin-screw working principle being at the forefront of them. Their high efficiency especially with viscous media, but moreover the insensivity against free or entrained gas as well as some solids make them well suitable for such a service.

While transport distances of about 100 km can be achieved with a single pumping station, longer pipelines may require intermediate boosting, depending on their diameter, landscape profile as well as capacity necessary. The paper will highlight pipeline installations in Sudan and South America, including a special application for twin-screw pumps operating in series.

1 INTRODUCTION

Twin-screw pumps are used essentially in any industrial application since decades. This includes the food as well as the oil & gas industry. However, they are commonly used with media of elevated viscosity, when other working principles become less efficient. Figure 1 shows a cut away view of a typical twin-screw pump with a cast housing design. Timing gears connect the contra-rotating drive and driven shaft, each carrying a pair of screws, so that axial forces occurring are balanced. There is no metal-to-metal contact between these elements and the surrounding housing. The fluid normally is transported from the outboard ends to the inboard side of the pump. The intermeshing screws form chambers ("locks") of constant volume. The theoretical capacity of the pump is defined as being the chamber volume (four chambers) multiplied by the number of revolutions. The screws outer and inner diameter as well as the pitch defines the size of the locks. The differential pressure as well as the fluid viscosity influences the actual capacity. The delta p across the pump causes backflow ("slip") through the clearances between the rotating elements. These losses are decreasing with an increased liquid viscosity. Twin-screw pumps are self-priming once initially filled with liquid, and have very good suction capabilities.

Fig. 1 Twin-Screw Pump

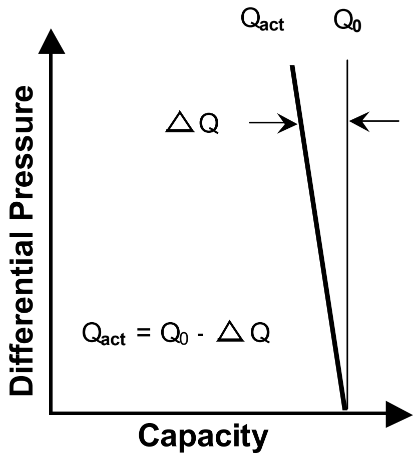


As the pump only transfers a volume from suction to discharge, no pressure is created internally. Just a response to the downstream backpressure is given. An integrated spring loaded relief valve prevents the pump from being over-pressurized. It allows for an internal circulation in case of backpressure being too high.
The mechanical sections are grease or oil bath lubricated, and sealed from the pumped fluid by means of mechanical seals. A number of well-approved seal suppliers offer all kinds of possible standard solutions for the various services in question as well as special designs.

2 CHARACTERISTICS

Figure 2 shows a typical twin-screw pump performance curve. This curve is valid for a certain speed only. When speed is increased, the curve for Q_o or Q_{act} respectively just moves to the right. The difference between Q_o and Q_{act} at a given differential pressure is the backflow ΔQ, which is influenced by the product's viscosity. A higher viscosity will lead to a more vertical gradient of Q_{act}. As can be seen, this type of working principle is very little dependent on product viscosity.
Oil field pipeline applications quite often have a sensitive discharge pressure scenario, especially for trunk- or gathering lines. Many different liquid streams are entering, and none of them should create any obstacle for others. Subsequently discharge pressures need to be "just at value". A positive displacement pump only responds to its downstream pressure, and no difficulties are envisaged in this regard.
Operators have to consider that even if e.g. crude oil to be exported is stored in tanks open to the atmosphere, it may still contain some gas. Certainly in most cases a vapor recovery system is installed. However, depending on the crude oil composition, some flashing make take place in the suction line. But even standard twin-screw pumps are well capable of handling a certain amount of gas due to their volumetric character.
Furthermore a reasonable amount of solids contained in the product can be tolerated, as there is no metal-to-metal contact between the rotating partners.

Fig. 2 Capacity vs. Differential Pressure



All kinds of drive systems are suitable, incl. gas and diesel engines as well as hydraulic motors. The pumps usually operate with low to moderate speeds, i.e. 1500 to 1800 rpm. This results in a very sensitive transfer, i.e. there is little shear stress imposed on the liquid. It should further be mentioned that twin-screw pumps are nearly pulsation free.
The following examples describe successful installations of twin-screw pumps in various crude oil pipeline applications.

3 SUDAN

Several high-pressure twin-screw pumps have been installed in the Sudanese provinces of West and South Kordufan southwest of Khartoum, the capitol of the Republic of Sudan. The Fula pipeline leads out of the oil field over 700 km to the Khartoum refinery. Final products are then pumped for export to Port Sudan at the Red Sea. At its final expansion stage this pipeline will have 4 intermediate pumping stations, each one equipped with 3 diesel engine driven high pressure twin-screw pumps for a differential pressure of close to 100 bar. While the product viscosity ranges between 500 to 1500 cSt, the high wax content of 13.5 % forms an additional challenge (Table 1).

Table 1 Sudan Operating Parameters

		Fula Pipeline	Melut – Port Sudan
Capacity each pump	m³/h	198	75
Differential Pressure	bar	97	97
Product viscosity	mm²/s	up to 1500	up to 1266
Cloud point	deg. C	n.a.	64
Power installed	kW	1700, diesel	630, electric
Pipeline size	inch	24	32
Pipeline length	km	700	1500

Another example is the pipeline from the oil fields in the Melut basin via Khartoum to Port Sudan. Six pumping stations, each equipped with two additional twin-screw pipeline start-up pumps, can be found along the 1500 km pipeline, having a 32” diameter. The final expansion state will see about 3,300 m³/h (500,000 BPD). While the crude oil is normally transferred with multistage centrifugal pumps, the pipeline can only be started after a shut down using twin-screw pumps. This is due to “frozen” or “gelled” pipeline content. The cloud point of the crude oil is 64 deg. C, see table 1.

4 VENEZUELA

In Venezuela extra heavy crude oil is produced in the Orinoco belt. Directly at the wellhead or already downhole respectively it is diluted with Naphtha or Meza crude to obtain a better flow behaviour. At a field gathering station the crude oil is stored in covered tanks, from where it is exported to the next central station. The pipeline has a length of approximately 40 km and a diameter of 30 inch. Due to the high viscosity, a considerable amount of gas is still entrained, forming a specific challenge for the export pumps. In 2005 multiphase pumps, based on the same working principle, therefore have exchanged standard twin-screw pumps. Those pumps are designed to even handle 100 % of gas for a short period. Out of the five pumps installed, four are continuously operating while one pump is on stand-by.

Table 2 Venezuela Operating Parameters

Capacity each pump	m³/h	596
Differential Pressure	bar	up to 41
Product viscosity	mm²/s	up to 1200
Gas content	%	up to 15
Power installed	kW	1120, electric
Pipeline size	inch	30
Pipeline length	km	40

5 ARGENTINA

High-pressure twin-screw pumps were installed 2007 at a crude oil export station in the Neuquén area in Argentina. The liquid is pumped via a 12 “ pipeline of 80 km in length to the final sales point. As the viscosity range is quite considerable (see table 3) the decision was made in favor of twin-screw pumps. While analyzing the liquid flow behavior a system head curve (fig. 3) was evaluated. Due to certain soil temperatures during the winter season, a considerable pressure peak in combination with a flow of nearly 120 m³/h was found. Please note that the pipeline is mostly buried. This peak of about 94 barg made it necessary to run two of the three pumps installed in series. As the normal pressure scenario is well below the pumps capabilities it was decided that an investment in stronger pumps would not be favorable.

Figure 3 System Head Curve

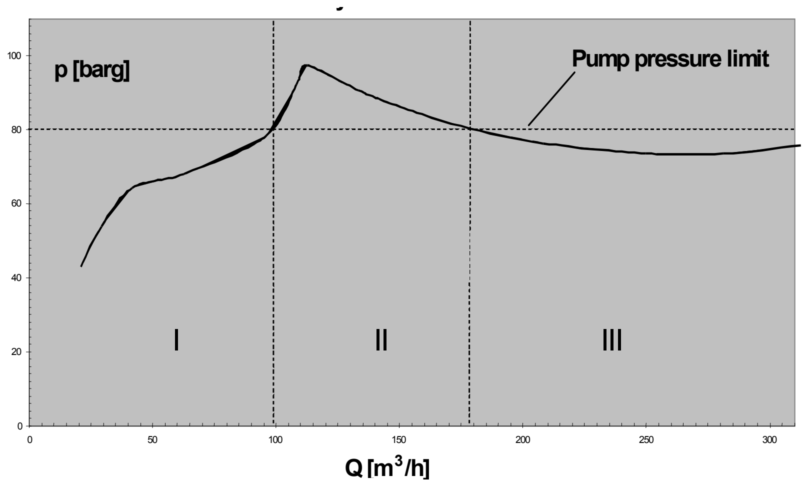
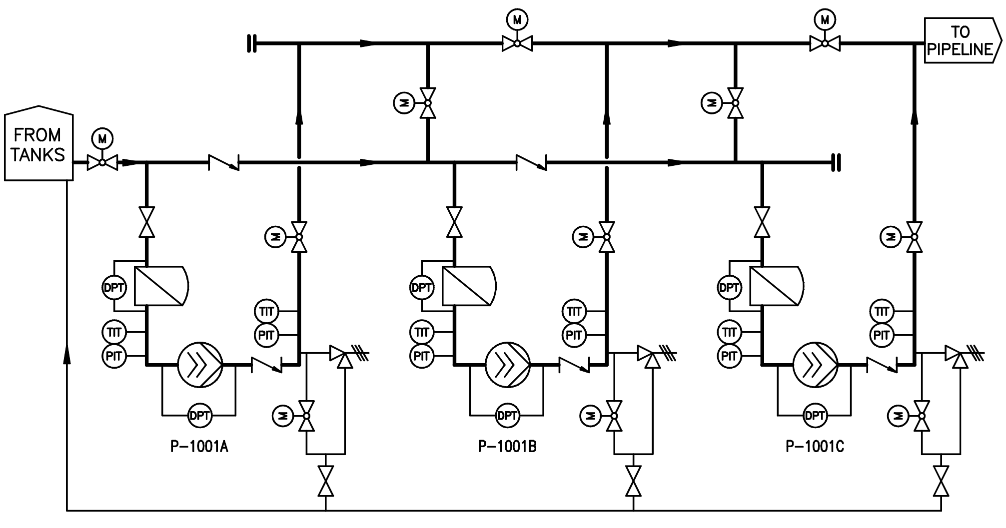


Table 3 shows the maximum operating parameters for each of the three pumps installed. While during phase I of figure 3 it is sufficient to run only one pump, two pumps are operating in parallel during phase III. For phase II two pumps would work in series, while the third pump always is kept stand-by. However as can be seen in the simplified P&I diagram (fig. 4), all available pumps can be placed in the respective process flow as may be needed.

Table 3 Argentina Operating Parameters

Capacity each pump	m^3/h	140
Differential Pressure	bar	max. 76
Product viscosity	mm^2/s	50 – 900
Power installed	kW	550, electric
Pipeline size	inch	12
Pipeline length	km	80

Figure 4 Simplified P&I Diagram



6 CONCLUSION

Twin-screw pumps have been used in pipeline services for decades. They especially have an excellent track record for viscous media, e.g. heavy crude oil, which is quite often heated for viscosity reduction. Their insensitivity against changing operating parameters and variation of the viscosity of the media being pumped is remarkable. All kinds of drivers may be used, which enables their installation also in very remote areas. Twin-screw pumps may be installed in parallel to obtain a higher flow rate combined with or in series for higher discharge pressures. While the first configuration offers a high operational flexibility, the latter one may save on investment cost for stronger pumps. Furthermore they may be used as pipeline start-up pumps, when the liquid has a tendency to “freeze”, e.g. with a high wax content being present.