

# Rotary Pumps On Pipeline Services

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## ABSTRACT

Pipelines handling liquids in excess of about 500 SSU viscosity will normally use rotary, positive displacement pumps both for optimum efficiency and, frequently, lower initial cost. This paper provides some insight into the application of rotary pumps to some of the unique requirements facing users of pipelines in crude oil transport, electric utility power generation and general industrial needs. Coverage includes pumping system designs, flow control on variable flow systems, serial pump operation on multi-station pipelines, key components that help ensure reliable pump operation and maintainability

Pipelines are used to transport a broad range of liquids, including crude oils, fuel oils, refined products such as gasoline, as well as water, specialty chemicals and others. Lines can be as short as several dozen feet to hundreds or even thousands of miles long. They can cross state or country boundaries. The modern world relies upon safe, efficient operation of all manner of pipelines, both liquid and gas. Oil producers, pipeline transport companies, refineries and power plants are probably the largest operators of pipelines.

## TYPES OF PIPELINE SERVICES

Pipeline services can be broadly categorized as loading/unloading, local transport and long distance transport. Examples of load/unload include pumping a relatively short distance from or to rail cars, tank trucks, barges or tanker ships. These services are typically intermittent, perhaps eight or fewer hours per day, perhaps not every day of the week. Differential pump pressures are usually low, less than 125 psid. The combination of low power and intermittent use makes pump operating efficiencies less important than in other services.

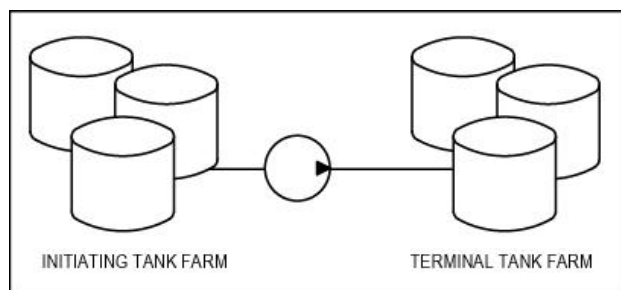


Figure 1 – Simple Pipeline System

Local transport would be defined as a single pumping station installation with line lengths less than 50 miles. Design operating pressures can reach 1450 psig or more. Local or national regulation may dictate maximum pressures. These pipelines can be intermittent or continuous duty services and can range from modest power levels to many hundreds of horsepower or more.

Long distance transport is usually more than 50 miles and includes multiple pumping stations along the length of the pipeline. These pipelines normally operate around the clock at partial or full capacity. Controls and instrumentation tend to be more sophisticated and automated. Long distance pipelines will frequently operate at variable station flow rates depending on product demand at the end terminal. Pumping stations will normally have three or more pumps with one in standby mode (three half-capacity pumps). If pipeline capacity is to be increased over time, more pumps may be added to each station.

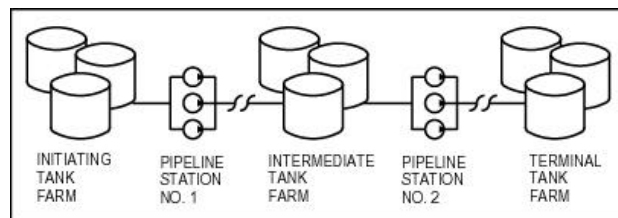


Figure 2 – Multistation, Tank System

## PUMPING STATIONS

Pumping stations for liquid pipelines can be as simple as a single pump located adjacent to a supply tank pumping liquid down the pipeline to a receiving tank (Figure 1). The supply and receiving tank level switches can control the pumping cycle by starting or stopping the pump at appropriate minimum and maximum tank liquid levels. Longer pipelines needing intermediate pumping stations can be handled in one of two basic arrangements. The first is to use storage tank(s) at each station (Figure 2). The upstream station pumps to the downstream station's tanks. The downstream station pump(s) take suction from these tanks and send the liquid further downstream. This is a simple, reliable method of long distance transport. Pumps are started or stopped depending on liquid level in tanks. It has several disadvantages. The cost of storage tanks, dykes and tank condition monitoring are not small. There is also product in "inventory" in the tanks that does not help a business's cash flow. The alternate arrangement is a "tight" system leaving

the pumping stations in series with each station's pump(s) taking suction from the pipeline (Figure 3). This has the advantage of eliminating the need for storage tanks but requires control over each pumping station in the pipeline such that exactly the same flow rate is going through each station--more on that later.

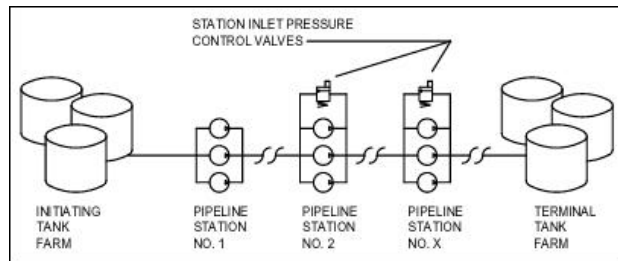


Figure 3 – Multistation, Tight System

### TYPES OF PUMPS APPLIED

Most pipeline pumps are centrifugal units. When the product being transported is always a low viscosity liquid like water, gasoline, diesel oil or very light crude oil, centrifugal pumps are cost-effective, reliable and efficient. However, as the liquid viscosity increases, the frictional losses within a centrifugal pump quickly reduce pumping efficiency dramatically (Figure 4). For this reason, rotary, positive displacement pumps are often used when products such as heavy crude oil, bunker fuels (no. 6 fuel oil), low sulfur fuels, asphalt, Orimulsion® (a manufactured boiler fuel emulsion of 30% water and 70% bitumen) and similar need to be transported. The energy costs of operating a pipeline can represent close to 50% of total operating costs, so pump operating efficiencies play a critical role in profitability. Table 1 illustrates differential annual operating costs for two real examples of centrifugal pumps vs rotary pumps.

Parameter	Centrifugal	Rotary
Type	6 stage	3 screw
rpm	3500	1750
Cst	200	200
psid	765	765
gpm	410	410
bhp	395	229
Efficiency %	45	81
Annual energy cost at \$0.07/kw-h	\$180,449	\$104,615

Table 1 – Operating Costs Comparison

While there are a great many types of rotary pumps, the most common on pipeline services are two and three screw pumps, gear pumps (internal and external) and vane pumps for low pressure services. Two and three screw pumps are used for higher pressure services, especially at medium to high flow rates. Table 2 shows the approximate maximum flow and pressure capability for each type, not necessarily achievable concurrently.

Type	Maximum gpm	Maximum psid
Gear	1500	250
Vane	1000	250
2-Screw	5500	1500
3-Screw	3400	2000

Table 2 – Rotary pump flow and pressure ranges

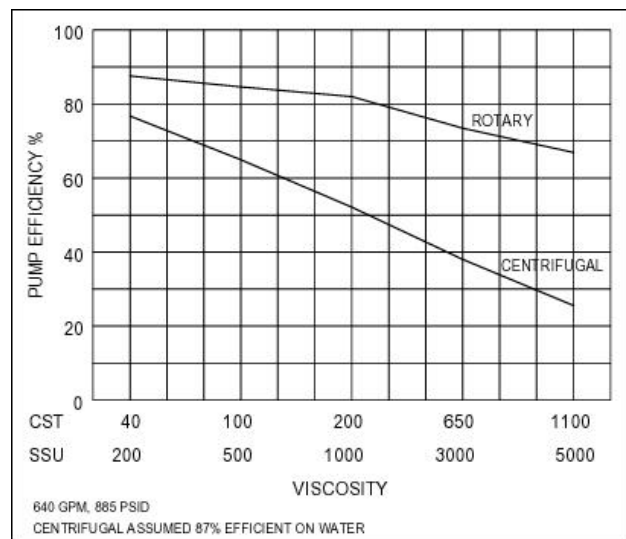


Figure 4 – Rotary Vs Centrifugal Efficiency

Gear and vane pumps, Figure 5, tend to have the lower first cost and may or may not have the best life cycle cost. They will normally operate at relatively low speeds requiring speed reducers on all but the very smallest sizes. Multiple screw pumps, Figure 6, move liquid axially rather than in a radial direction, so fluid velocities are relatively low even when directly driven at four and six-pole motor speeds (1,800 and 1,200 rpm at 60 Hz, 1,500 and 1,000 rpm at 50 Hz). Efficiencies remain high over a much broader range of

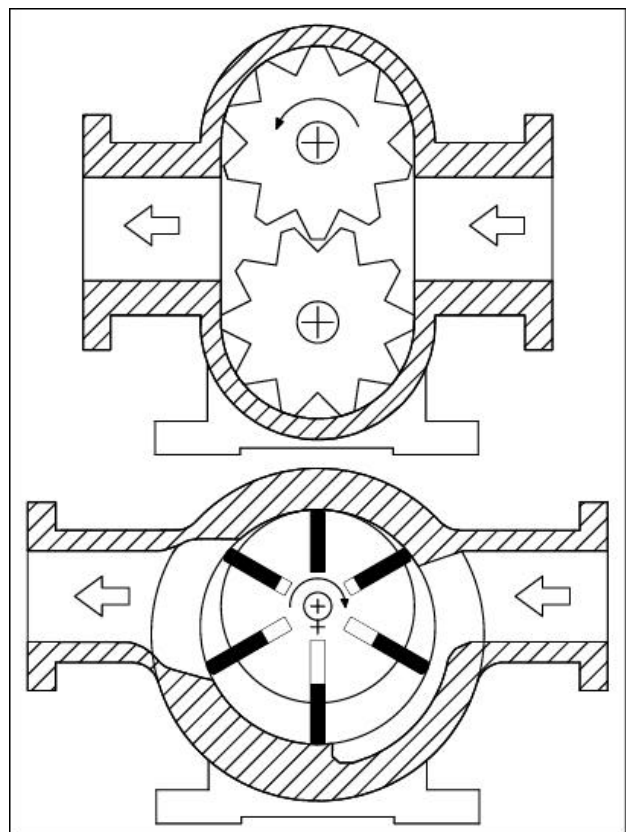


Figure 5 – Gear (top) and Vane Pump

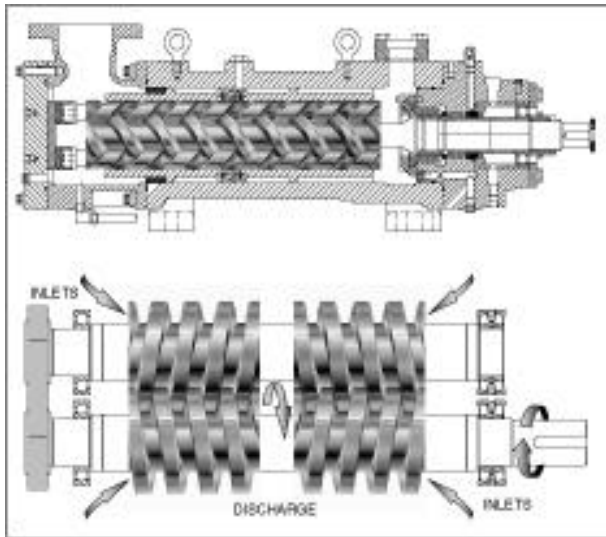


Figure 6 – Multiple Screw Pipeline Pumps

differential pressure than centrifugal pumps. Figure 7 shows 12,000 hp of installed two screw pumps (15 pumps in all) that are used to load Orimulsion® tankers eight miles offshore. Figure 8 illustrates a diesel engine-driven three screw crude oil pipeline pump operating in Guatemala at 1,400 psig.

### SPECIFIED OPERATING REQUIREMENTS

Obviously, pump and driver specifications will be needed to acquire equipment that will perform to requirements. Unless your organization has these talents in-house, an engineering firm will be needed to explore the pipeline requirements. As it relates to rotary pumps, as a minimum, the following will need to be defined:

1. number of pumping stations
2. number of pumps per station
3. possible range of
  - pump inlet pressures
  - pump discharge pressures
  - liquid temperature range
  - liquid viscosity range
  - per pump flow rate range
  - particulate content
  - upset conditions
  - static conditions
4. driver requirements
5. pump instrumentation
6. pump leak detection

Particulate content can range from unknown (take your chances) to specific weight percent of sediment, sand, etc. On liquids containing abrasives, pump life is inversely proportional to something between the square and cube of pump speed. Operating larger pumps at lower speeds will increase initial cost but can save on maintenance costs over many years. Another proven technique to extend pump life in abrasive environments is to select pumps with effectively

more stages than needed just for pressure capability. For example, every wrap in a screw pump acts as a pressure stage, similar to a multistage centrifugal pump. More stages reduce the pressure rise per stage, reduce the slip flow (volumetric inefficiency) and spread out the wear. The result is extended pump service life and, frequently, higher average efficiency over time.



Figure 7 – 15 Twin Screw Pumps for SUBSEA Pipeline

Product leak detection could be a critical element in both pumping station safety and environmental contamination. Unless there are observant attendants on site at all times, automatic alarm or shutdown should be considered in the event of product leakage from any source. Rotary pumps most commonly use mechanical seals to contain pumped product within the pump casing. A mechanical seal will wear, can fail catastrophically and product under pressure can leak large volumes in short time periods. Many pumps used for pipeline services can be equipped with various seal leak detection schemes to alert/alarm or shut down in the event of excessive seal leakage.



Figure 8 – Diesel Driven 3-Screw Pump at 1400 psi

Driver selection depends on available power sources. In remote areas, diesel engines are usually chosen. They provide some range of speed and, therefore, flow control of

the pumps. By far, the most common drive is a fixed speed electric motor, although variable frequency drives are becoming more popular. They can improve station efficiency by avoiding the necessity of drawing power to pump flow that is to be bypassed around the station (wasted energy). Spacer couplings are highly recommended between the pump and its drive. They allow access to pump shaft-end seal and bearing as well as motor shaft-end bearing.

Upset conditions and static conditions need to be assessed during pipeline design. Most rotary, high pressure pumps cannot tolerate anything close to discharge pressure at their inlet (suction) port. In a tight system, if an upstream pumping station is started and the downstream station is not started in very close synchronization, the downstream station may see excessive pressure on its inlet side. A low pressure set inlet side relief valve may be necessary together with an over-spill tank and appropriate instrumentation.

Instrumentation tends to be a very owner-specific issue. Some systems have only a few pressure gauges. Others include bearing temperature detectors, vibration detection, inlet and outlet pressure transducers, temperature transducers, all sufficient to get a good picture of what is happening at a pumping station, sometimes from many hundreds of miles away.

## PUMP HEATING AND/OR COOLING

If the product being pumped is so viscous that heating it before pumping is necessary, then it will probably be prudent or essential to provide a means of preheating the pumps so they are not faced with sudden introduction of hot liquid into cold pumps. Depending on available utilities, pumps can be jacketed for use of heating mediums such as steam or hot oil. Heat tracing with electric thermal wire is also an option. The outside of the pump will need to be insulated to contain the heat. Heating and insulation systems must take into account pump maintainability if the heating or insulating system must be first removed to service the pump. Be sure to avoid applying heat to timing gear cases or pump bearings. In some instances, these pump components may actually need cooling to operate for extended periods.

## PUMP PROTECTION

Like most other pumps, rotary pumps are vulnerable to premature wear or failure from too little or too much inlet pressure, too high a discharge pressure, excessive inlet temperature, dry running and ingestion of foreign material (weld rod, wire pieces from cleaning brushes, etc). In addition, if the liquid pumped is inherently “dirty,” like many crude oils and bunker fuels, then pump wear will be a normal part of operating pipeline pumps and one should prepare for that eventuality.

Systems need to be instrumented to at least alarm if any of these parameters approach a limiting value. If pumps are unattended most of the time, then automatic shutdown is the only protection from catastrophic pump failure. Use of inlet

strainers is highly desirable provided they are instrumented to detect excessive pressure drop and cleaned when needed. Without regular monitoring and cleaning, strainers eventually will accumulate debris to the point that the pressure loss of liquid going through the strainer will allow pump inlet pressure to fall below the minimum allowable. Worse still, that pressure drop can cause the strainer element to collapse. On collapse, all the accumulated debris as well as the strainer element will arrive at the pumps inlet. Nothing good will come of this!

As with any positive displacement pump, a pressure relief device is essential to safe operation. The “shutoff head” of a positive displacement pump can be enormous; far above the pressure rating of any system component. A relief valve is normally installed at each pump discharge with the valve outlet connected back to the supply tank (preferred) or to the pump inlet piping as far from the pump as practical.

## SYSTEM CONSIDERATIONS

When starting a rotary pipeline pump with the pipeline already full, the system must provide for the time required to accelerate the liquid from zero velocity to final velocity. There may be 50 miles of product that needs to get to 10 ft/sec. This is normally accomplished with an electric operated valve around each pump that bypasses discharge flow either back to the supply tank (preferred) or back to pump suction. The valve is open on pump startup and closed gradually as the flow velocity in the pipeline builds. If bypassing back to the pump inlet piping, go as far away from the pumps as practical. This will maximize the mass of liquid available to absorb the driver power draw that is not yet going down the pipeline while the bypass is not fully closed.

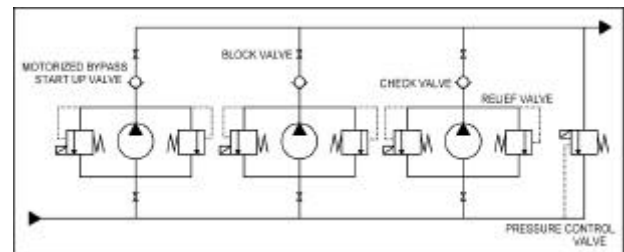


Figure 9 – Tight Series Pump Operation

Flow control can be achieved in several ways. Variable frequency drives are becoming more affordable in larger sizes. Since rotary pump flow is directly proportional to speed, control is fairly straightforward. In tight systems with fixed speed drivers, pumping station variable flow is achieved first by how many of the station’s pumps are in operation and second by bypassing flow around the station to control how much total flow leaves the station. Figure 9 is a simplified schematic of such a system. The bypass valve senses station inlet pressure. It bypasses whatever flow is necessary to control station inlet pressure at set point. If the station inlet pressure rises, less flow will be bypassed and more flow will therefore leave the station.

## MAINTENANCE

Maintenance for rotary pumps is not very different from any other pump. Hopefully, the installation provided both space to access the pump for service as well as some shelter from the elements. Since rotary pumps have relatively close internal running clearances, be especially careful to achieve and maintain good pump-to-motor shaft alignment. Avoid pipe strain at all costs for the same reason. If pumping station downtime is a serious matter (usual), then have an installed standby pump ready to take over as well as critical spare parts. If a pump “goes down,” try to identify the cause before starting another one. Sadly, too many times a series of failures is allowed to occur before enough time and effort is expended on root cause analysis.

Many pipeline pumps have service parts that need to be removed from both ends of the pump. Spacer couplings go a long way in easing the drive end service. Avoidance of wall or objects close to the pump end opposite the driver is usually necessary to avoid the need to disconnect piping and remove pumps to a bench area.

Some pumps are, in fact, better maintained on a bench in a maintenance area where space to perform the work is

more available, components can be more easily assessed for their condition and new parts can be installed more correctly.

## CONCLUSIONS

Rotary, positive displacement pumps can play key roles in reliable, efficient, effective transport of liquids over short or very long distances. They are an optimum choice where efficiency is a strong driver of pump selection and operation. There is extensive, very long history of successful applications of rotary pumps to pipeline transport.

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