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Multiphase Pumps for 250,000 bbl/D Field Development

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Abstract

The production from an entire oil field, or a substantial field area can be achieved by using multiphase pumps (MPP), either on their own or in conjunction with some well activation techniques (electro submersible pumps, gas lift, etc). MPP are applied for oil fields with a GOR generally in the range of 100 to 1000 scf/bbl, extending sometimes to higher values.

It can be seen from this paper that MPPs can realistically be considered to represent a viable and proven solution for oil field developments up to about 250,000 bopd. This is due to the development of higher capacity helico-axial pumps which are now capable of handling total volumetric (actual flow at pump inlet: oil, gas and water) capacities in excess of 500,000 bpd (3,300 m^3/h).

The use of MPP is especially advantageous for remote fields in inhospitable environments where unmanned facilities are preferred.

A case is described where four high capacity and high power (up to 8,000 HP or 6,000 kW) helico-axial multiphase pumps have been selected to overcome a pipeline capacity restraint at the Priobskoye oilfield in Siberia. This field is operated by JSC Nefteyugansk, part of Yukos.

Introduction

Multiphase Pumping is essentially a means of adding energy to the unprocessed effluent which enables the liquid/gas mixture to be transported over long distances without the need for prior separation or flaring.

Helico-Axial Pump Design

The Sulzer range of multiphase pumps is based on the helico-axial concept (Poseidon).

The pump is a multistage rotordynamic turbomachine which enables a liquid/gas mixture to be pumped in a centrifugal machine without incuring phase separation. The hydraulic design of the pump is adapted to take account of the decreasing volumetric flowrate arising from the compression of the gas content. The continuously open design of the hydraulic passages and axial flow path ensure that the pump is very tolerant of sand and suspended solid particles entrained in the effluent.

The mechanical design is based on API 610 although because of the requirement for the pump to handle a high gas content the rotordynamic design is based on the API 617 specification for compressors.

The pump is of the barrel casing design with an axially split inner casing, incorporating conventional mechanical seals and bearings. A pressurised seal system (similar to a standard Plan 53 system) prevents gas leakage or solid particles contaminating the bearing area and ensures that a liquid film is always present at the seal faces even when the pump is operating under dry running conditions. An overpressure of approximately 5-10 bar is maintained between the seal fluid circuit and the product side of the mechanical seal.

The inner casing and hydraulic components is generally supplied as a cartridge or pull-out block for ease of maintenance. Consequently the pump (similar to a conventional barrel casing pump) can be retrofitted with a cartridge of an alternative hydraulic design to suit changing conditions later in the life of a field if so required.

Applications

First applications of this technology were typically lower flow installations or smaller scale projects such as TotalFinaElf's Pécorade field in France where the low pressure wells were boosted to the HP separator thereby enabling gas which was previously flared at the LP separators to be recovered. This application prolonged the life of the field by a number of years.

More recently multiphase pumps have been used on larger scale applications enabling cost savings to be realised due to the elimination of the requirements for conventional processing facilities, especially in marginal, hostile environments.

Field Development Alternatives

Comparing alternative options and determining the optimum solution for the development and production of a field is a complex task when one considers the number of parameters involved, the variety of possible situations and changes which will inevitably occur over the field life.

Typically there are three phases of field life:-

- Natural flow when the Well Head Flowing Pressure (WHFP) is above the required pipeline inlet pressure. In this case no pressure boosting is required.
- Wells Eruptive. Over time the water cut increases and the WHFP declines, meaning that one must either accept a lower production rate or add energy to the effluent stream. Ways of achieving this include gas lift, downhole pumps, a separation system or more recently multiphase pumping.
- Wells Non-eruptive: i.e. the wells do not have enough energy to flow to the surface. In this case multiphase pumping can be used in conjunction with either gas lift or downhole pumps to minimise back pressure at the wells, thereby reducing well activation requirements.

Criteria for using Multiphase Pumps

Multiphase pumps are a valid option for the second and third scenarios due largely to the development of higher capacity helico-axial pumps which are now capable of handling total volumetric (actual flow at pump inlet) capacities in excess of 500,000 bpd (3300 m^3/h)

All installations where multiphase pumps have been selected based on engineering studies which have shown that this solution is better and more economical than conventional separator technology.

This economic advantage is largely due to the fact that less equipment is required. An earlier study has shown (1) that in the case of a 20,000 bpd field, where the total production has to be transported over a distance of 35 km, a multiphase pump installation could prove to be approximately two thirds of the cost of a conventional separator installation with a pump, compressor module and two pipelines.

In practice cost savings of 30% as compared to a conventional separation system have been achieved in some recent installations such as the TotalFinaElf Dunbar project.

There are also several practical reasons why helico-axial pumps are well suited to full field developments:-

- Compared to the traditional method of separation where all wells have to work with the same inlet pressure, a variable speed multiphase pump allows a controlled reduction of the well head pressure.
- It is often difficult to obtain accurate reservoir and field operating data, particularly for new fields. Such data and parameters will evolve over the life of the field thereby changing the demands imposed on the pumps. An installation based on helico-axial multiphase has a high degree of inherent flexibility achieved as follows:-
  - By changing the speed of the pump.
  - By varying the number of pumps and phasing in the installation of pumps.
  - By changing the number of stages (using a cartridge equipped with live and dummy stages which can be later changed into live stages) to suit changing pressure requirements.
  - By fitting the pump with a new internal cartridge with different hydraulic characteristics if capacity requirements change significantly at some point in the life of the pump (e.g gas breakthrough).

Also in the case of larger pumps these can be either electric motor or gas turbine driven if a suitable fuel source is available.

Multiphase pump stations can also be designed for unmanned operation and are therefore particularly suited to operation in arduous and hostile environments.

System Criteria

An optimum MPP solution is best achieved by establishing an ongoing and constructive dialogue between the field architect and the pump designer. Indeed it is important to understand the complete transportation issue, mainly the production profile over time (reservoir, well data) and then optimise the pump selection and export pipeline configuration accordingly.

Important aspects are the flow regime under multiphase conditions and the associated pressure losses along the pipeline, also flow assurance issues such as hydrate formation, wax deposits, and sand content.

To determine the flow regime, pressure and temperature gradients along the pipe, simulation tools are used. Generally a steady state analysis is sufficient.

However when more complex pipeline configurations are to be considered and depending on the liquid and gas produced, the actual multiphase flow regime in the pipe may not be stable under all operating conditions. In such cases a transient analysis may be preferred.

Compositional transient simulation tools such as the TACITE code, developed by IFP (Institut Français du Pétrole) together with TotalFinaElf take into account complex fluid effects and are able to simulate transient and steady state multiphase flows accurately.

MPPs for Yukos: Priobskoye Field, Siberia

The Priobskoye field which was discovered in 1982, is currently one of the largest partially developed oil fields in Western Siberia, covering an area of 5,446 sq km.

Yukos' operating company JSC Yuganskneftegas has the licence to develop the northern part of the field which covers an area of 3,000 sq km.

Oil reserves here are estimated at 621 million tones (4.5 billion bbl). In 1997 and 1998 output amounted to 1.062 and 1.195 million tons of crude oil respectively. By the end of 1998 more than 520 wells were drilled,. In 1999, Yukos' chairman, Mikhail Khadorkovsky, said that "Yukos regards the Priobskoye field as its most important strategic project"(3).

The development of the field started about 10 years ago on the left bank of the river Ob, where the treatment facilities are located. In 2000 the right bank alone produced 1.2 million tons (approximately 24,000 bopd), however, the recent exploration and drilling development revealed the potential of the right bank to produce 4.4 million tons of oil (87,000 bopd) in 2001. At present oil is produced using downhole pumps and transported along a single 33 km long 426 mm diameter from the right bank to the treatment facilities on the left bank. However the maximum capacity of this pipeline is 1.8 million tons per annum (36,000 bopd) which therefore represents a significant constraint.

Any development must also take account of environmental issues. In spring and summer 85% of the area is flooded by the high waters of the river Ob, with extensive swamp conditions making access very difficult. Site temperatures range from -55°C in winter to +35°C in summer. It is also an environmentally protected area with a high priority being given by Yukos to avoiding any damage to the ecosystem of the flood plain.

Debottlenecking Options

A conceptual plan for the development of the field was carried out by Yukos which compared multiphase pumping to the conventional alternative (a new separation plant on the right bank or additional pipes across the river).

A multiphase pumping station designed to transport the well effluent through the existing pipeline was selected for the following reasons:-

- No requirement for permanent manning
- Economically advantageous
- Ecological reasons (no flaring, leakage or venting to atmosphere, no first stage separation in an environmentally sensitive area).
- Increased capacity possible from the existing downhole pump by reducing the required head.

Pump Data

Sulzer co-operated with Yukos in preliminary studies of the transportation system enabling pumping conditions to be determined and a forecast of production volumes to be made. A phased pump installation programme was drawn up from this forecast which envisages the initial supply of two variable speed multiphase pumps with two additional pumps supplied later to cater for anticipated future increases in production.

The main operating characteristics of each pump are as follows:-

- Total Volumetric Inlet Capacity 500,000 bpd
- GOR 392 scft/bbl
- Discharge Pressure up to 800 psi (55 bar)
- Speed variable, up to 5800 rpm
- Driver Rating 6000 kW

Scope of Supply

Yukos' specification required the equipment to be installed in self-contained packaged and sheltered modules, to minimise site work.

There is one shelter for each pump containing:-

- Multiphase pump

- Electric motor, rated 6000 kW
- Speed increasing gearbox
- Seal system
- Lube oil system for pump, motor and gearbox
- Common air blast cooler for seal and lube oil system
- Motorised suction and discharge valves and non-return valve

A second shelter for each pump contains:-

- Variable frequency drive
- Motor control cabinet
- Low tension distributor cabinet
- Instrumentation panel
- Operators control room with work station.

A 35 kV/2.2 kV transformer is supplied for each pump, again in a protective enclosure.

A single common buffer tank is supplied to distribute the flow evenly to each pump.

Finally there is a common electric distribution shelter which houses a 35 kW switchboard and 2,400 volt transformers.

The buffer tank and electric distribution shelters are designed to suit four pumps i.e the two pumps supplied initially and an additional two pumps currently under manufacture.

Low Flow/High Flow Cartridge

After commissioning the first two pumps will initially be required to operate with a moderate differential pressure due to the fact that the export pipeline is sized for a higher capacity which will occur as production increases and additionnal pumps are phased in.

- Initially both pumps are supplied with destaged lower flow lower / pressure cartridges. A complete spare cartridge is also supplied.
- Then, when the third and fourth pumps are commissionned, additional live stages will be installed in the first two pumps.

The use of different cartridge designs means that the range of design duties covered by the pump will at different times in the life of the field vary as well as the differential pressure to suit the field requirements. This highlights the hydraulic flexibility afforded by the multistage helico-axial pump and the range of conditions which can be accommodated as regards both flow and pressure.

Operating and Control

In view of the fact that the station is often not easily accessible the pumps are designed to operate in automatic mode, and can be controlled from a remote control operation centre.The usual pump monitoring systems are provided in addition to which the control system enables the required pump speed to be set either manually or automatically.

Status

The first two pumps now installed will increase the capacity of the existing pipeline from about 36,000 bopd to about 93,000 bopd, i.e. the incremental production achieved by the installation of two multiphase pumps will be in excess of 50,000 bopd. When the next 2 pumps are installed and an additional pipeline brought on stream the station will then be capable of producing a total output of 200,000 bopd.

Conclusion

Multiphase pump technology represents an accepted and recognised economical option for full field developments producing up to about 250,000 barrels of oil per day.

In the case described here multiphase pumps were selected because they were more economical and offer a higher operating flexibility and phasing in of the investment for field development than conventional separator installations (where for example a gas compressor cannot be sized for a variable range of inlet pressures).

Experience has demonstrated the suitability of the pumpsets for installation in arduous environments, for unmanned installation, and the inherent flexibility of the helico-axial design.

Multiphase pumps are exciting, innovative and proven. They offer significant advantages and benefits to operators embarking on full field developments.

References

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