The whole package

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discusses developments in oil injected screw gas compressors (API619).

Typical requirements for process gas compressors in oil refining processes include the following specifications:

- Hydrogen rich gas (low molecular weight).
- High pressure.
- High compression ratio.
- Small to medium gas flow.

Until now, reciprocating compressors (API618) have been the preferred choice for oil refining plants worldwide to meet these requirements. However, they can also cause many difficulties during operation.

First of all, the reciprocating compressor is not often reliable and requires frequent maintenance, which means that a spare compressor is needed for continuous process operation. Major maintenance is often required within a short interval (approximately one to two years) due to its large number of sliding and wearing parts. Thus, the reciprocating compressor is a cost intensive machine that is not particularly suited for continuous and long term operation.

In the case of a process load change during operation, reciprocating compressors do generally consume less power than centrifugal compressors in turndown operation, but this normally takes step controls (i.e. 100% - 75% - 50% - 25%), therefore the power saving is not linear.

Furthernore, there are environmental issues with reciprocating compressors, such as noise, emissions, pulsation and vibration. This necessitates significant sound protection with limited accessibility, in addition to heavy structure and foundation to avoid excessive problems. The issue of environmental friendliness continues to grow in importance.

These problems have meant that there has long been the need to develop more reliable and less maintenance intensive process gas compressors for use in the oil and gas industry. With the current decline in the number of experienced specialists in rotating equipment, easy operation without any special attention to the compressors is particularly important.

Alternative compressors

At present there are two alternative types of process gas compressors available: the centrifugal compressor (API617) and the screw compressor (API619).

Both types offer greater reliability than reciprocating compressors, but have other technical difficulties to overcome in order to handle the requirements for process gas compressors in oil refining processes as described above.

Figure 1. Typical oil injected screw compressor package for refinery PSA unit, hydrogen tail gas service.

Centrifugal compressors are not suitable for hydrogen rich gas (low molecular weight), high compression ratio and small to medium gas flow. If applied, it would become multi casings (causing very high initial costs) and much less efficient.

On the other hand, screw compressors can easily handle hydrogen rich gas, high compression ratios and the small to medium gas flow, thanks to positive displacement, which is the same as reciprocating compressors. However, there is a problem with handling high pressure because its applicable pressure is as low as 30 barg (430 psig), which means that conventional screw compressors are not practical for the main process gas services in oil refineries; they have, however, been used successfully for H_2 rich tail gas compressors for the pressure swing adsorption (PSA) unit in oil refinery due to low discharge pressure requirements of 7 - 10 barg (100 - 150 psig) (Figure 1).

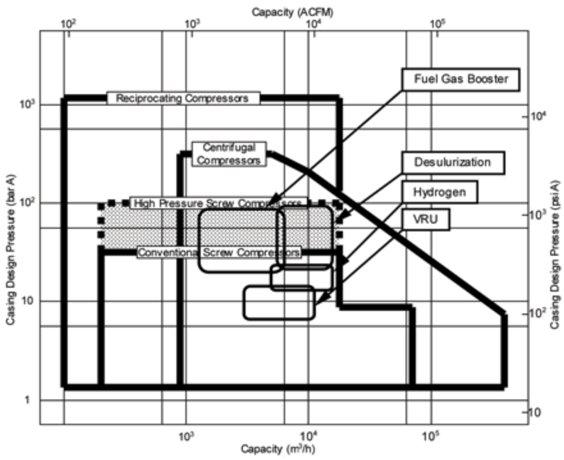

Figure 2. Chart with each type of compressor's typical applicable range.

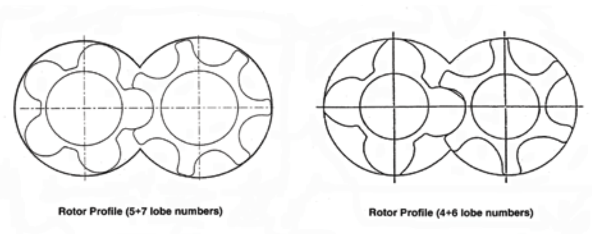

Figure 3. New rotor profile (5 + 7) vs. conventional rotor profile (4 + 6).

High pressure screw compressors

The situation changed dramatically after the high pressure screw compressor was developed in the late 1990s. With an initial handling capacity of up to 60 barg (900 psig), the applicable range has now been extended up to 100 barg (1500 psig), thereby solving the problem of high pressure and making it suitable for various process gas services in the oil industry (Figure 2).

The main benefits of oil injected screw compressors are:

- High reliability: no spare compressor required even for continuous operation.
- Less maintenance: very few wearing parts (mechanical seals) means lower running costs.
- Continuous operation: longer overhauling interval.
- No compression ratio limit: extremely high compression ratio can be handled by single stage.

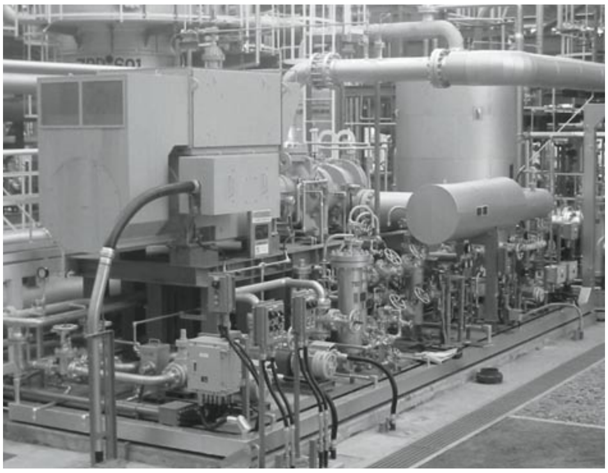

Figure 4. Typical oil injected screw compressor package for refinery desulfurisation, hydrogen recycle service.

- Simple structure (lower initial cost).
- Simple system (no gear, no seal gas unit).
- Power savings: easy turndown control through built-in slide valve (100% to 15% without step).
- Low noise: easy to achieve 85 dBA at 3 ft (1 m).
- No pulsation and vibration issues.
- No emission issue.
- No passing critical speed (screw compressor has a rigid shaft).
- Almost no influence of gas composition change (positive displacement).

Due to these benefits, the oil injected screw compressor has been developed for various process gas applications since 1970s. With its greater handling capacity, oil injected screw compressors can now be used for more applications, including hydrogen services, without the drawbacks of reciprocating compressors.

Figure 5. Typical oil injected screw compressor package for refinery platformer hydrogen service.

Figure 6. Typical oil injected screw compressor package for refinery offgas used fuel gas booster to gas turbine.

The robust, high pressure screw gas compressor was developed in the late 1990s by utilising various advanced technologies. One of the major developments is the design of its new rotor profile. All screw compressor manufacturers have been using the originally designed rotor profile, known as the '4 + 6 profile' (a combination of four male lobes and six female lobes), which was developed by the licensor (SRM) in Sweden. A new rotor profile called '5 + 7 profile' (five male lobes and seven female lobes) was also developed by Kobe Steel, Ltd in Japan in order to achieve the 100 barg (1500 psig) high pressure (Figure 3).

The oil injected screw compressor can now be used for the following applications:

- Hydrogen makeup and recycle services for refinery processes (hydrotreater, platformer, diesel and gasoline desulfurisation). The required discharge pressure range is 30 - 90 barg (430 - 1300 psig). Figures 4 and 5 offer an example of the screw gas compressor package.
- Natural gas booster to pipeline and at LNG receiving terminals. The required discharge pressure range is 70 - 90 barg (1000 - 1300 psig).
- Fuel gas booster to high efficient gas turbines. The required discharge pressure range is 40 - 70 barg (570 - 1000 psig). Figures 6 and 7 show the screw gas compressor package.

From an environmental point of view, these requirements are likely to grow more and more important in the future.

Description

Figure 8 shows a cutaway drawing of a typical oil injected screw gas compressor.

There are two rotors inside the casing, which contact each other at lobe surface via an oil film. Oil is supplied not only to the bearing and seal but also to the rotor chamber directly, and will act as lubricant, coolant and sealant in the rotor chamber. Typically, the male rotor is driven by a directly coupled two pole or four pole electric motor and drives the female rotor. An external gear unit is typically not used as the tip speed of the oil injected screw gas compressor is in the proper design range when driven at motor speed. As oil is injected into rotor chamber, the seal area between the lobe and bearing is no longer necessary; there is only one mechanical seal located at the drive shaft end.

There are typically sleeve type journal bearings on either end of the rotor lobes. Thrust bearings are

Figure 7. Typical oil injected screw compressor package for natural gas used fuel gas booster to gas turbine.

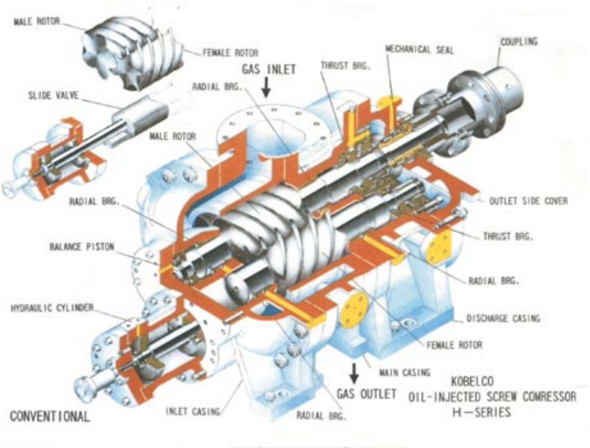

Figure 8. Typical cutaway drawing of oil injected screw gas compressors.

usually tilting pad type and are located on the outer side of the journal bearings.

The oil and gas mixture is discharged through the compressor discharge nozzle into an oil separation system located downstream of the compressor. Oil separated in the oil separation system is circulated in the compressor lube system.

An unloaded slide valve is located in the compressor just beneath the twin rotors and is used to adjust the inlet volume. The inlet volume of the compressed gas can be adjusted by moving the slide valve, which is actuated by a hydraulic cylinder. A typical schematic diagram for an oil injected screw gas compressor is shown in Figure 9.

Compressor lubricant oil is present in the process side, so the lube oil selection is very different from other types of machines. The bulk of the oil is separated in the primary oil separator, but a secondary coalescing oil separator may be used as an additional separator. Separation of oil is one of the important factors for the oil injected screw gas compressor. Typically, a combination of demister mesh pad and coalescing elements are used. For example, 0.1 ppm wt level can be achieved by combining the demister mesh pad and two stages of coalescing elements. Charcoal absorbers are occasionally used for more severe applications. Borocilicate micro fibre is a typical material used in coalescing elements and submicronic particles of oil can be separated from the compressed gas. Unlike reciprocating compressors, oil from the compressor has no deterioration by piston rubbing so that oil can be recirculated in the system as lubricant for a longer life. The lube oil circulation system consists of compressor lube lines, oil cooler, oil filters and oil pump. The oil pump may be double or single configuration. The design of a single pump system may be used when the pump is required only during startup. In such cases, after the compressor starts and the discharge pressure is established, oil can circulate in the system by utilising gas differential pressure between suction and discharge.

The slide valve is used to load and unload the compressor to maintain suction pressure or discharge pressure. There is a spool valve to switch over the oil lines to pressurise the slide valve cylinders to load side or unload side. Typical control range by slide valve is 15 - 100% step less by inlet volume.

Below is a list of some of the major and unique characteristics of the oil injected screw gas compressor:

- Power consumption savings through built-in slide valve. The slide valve (used as an unloader) adjusts the inlet volume of the compressor, leading to substantial power savings. Figure 10 shows the basic principle of the slide valve mechanism. The slide valve is located just beneath the rotors and moved in axial direction, and is moved typically by hydraulic cylinder with oil from the compressor lube oil line. Moving the slide valve to the suction side attains full load, and unloading is achieved by moving the slide valve towards to discharge port. At full load position, the entire length of the rotor is utilised to draw the gas so that inlet volume of the compressor can be maximised. By moving the slide valve to the unloaded position (i.e. discharge side), the length of the compression chamber is shortened. As a result, inlet volume of the compressor is reduced. Compression is achieved with less inlet volume of the compressor so that theoretical brake horsepower is reduced.
- High compression ratio limitation. Since the oil acts as coolant and sealant, the limit on compression ratio is very high. Discharge temperature can be adjusted by oil flowrate, i.e. oil can be injected into the rotor chamber to absorb the compression heat in the oil injected screw gas compressor. When a very high pressure ratio is required, a tandem arrangement of two stage compressors combined in one casing is employed to achieve better efficiency. Typically, this tandem arrangement is used when pressure ratio is larger than 7:1 and can be applied to ratios of more than 50:1. Typical cutaway drawing of a tandem arrangement oil injected screw gas compressor is shown in Figure 11. Since oil will act as coolant at intermediate stage, an external intercooler for intermediate stage is unnecessary.
- Low maintenance cost. Due to the lube oil system, the rotors and many other parts of the compressor have an oil film on their surfaces. The life of the rotors is long enough so that a spare set is not required. The mechanical seal is typically one per casing and the

total structure of compressor is quite simple so that the maintenance cost is quite low.

- Single skid arrangement. The compressor and lube oil system are integrated and packaged on a common single skid. Thus, transportation and installation is completed in a short period.
- No cooling water jacket/no gas bypass cooler. Since oil acts as the coolant in the compression process, discharge temperature can be controlled by the oil injection flowrate or oil temperature so that the casing structure is made simpler by elimination of a cooling water jacket. The gas bypass cooler can also be eliminated by oil cooling.
- Variety of oil selection to meet the handled gas. Selection of oil is driven by the need to be compatible with process gas. Mineral based oil as well as synthetic oil has recently been used to expand the application range of oil injected screw gas compressor. Hydrotreated mineral based oil has typically been used, but many have been changing to synthetic oil. There are two kinds of synthetic oil: poly alpha olefin (PAO) and poly alkylene glycol (PAG). For a process with a heavy hydrocarbon, both mineral based oil and PAO are subject to dilution; however, less dilution can be expected with PAG. There is almost no difference for dilution ratio by process with heavy hydrocarbon between mineral based oil and PAO, whereas PAG once again offers less dilution. Dilution rate: mineral oil = PAO < PAG. PAG is hygroscopic; however, it has extremely less dilution for heavy hydrocarbon compared to mineral oil. By using PAG oil, oil injected screw gas compressors can be used for heavy hydrocarbon applications.

Conclusion

The robust, high pressure oil injected screw gas compressor offers many benefits as an alternative to reciprocating compressors for heavy duty process gas applications.

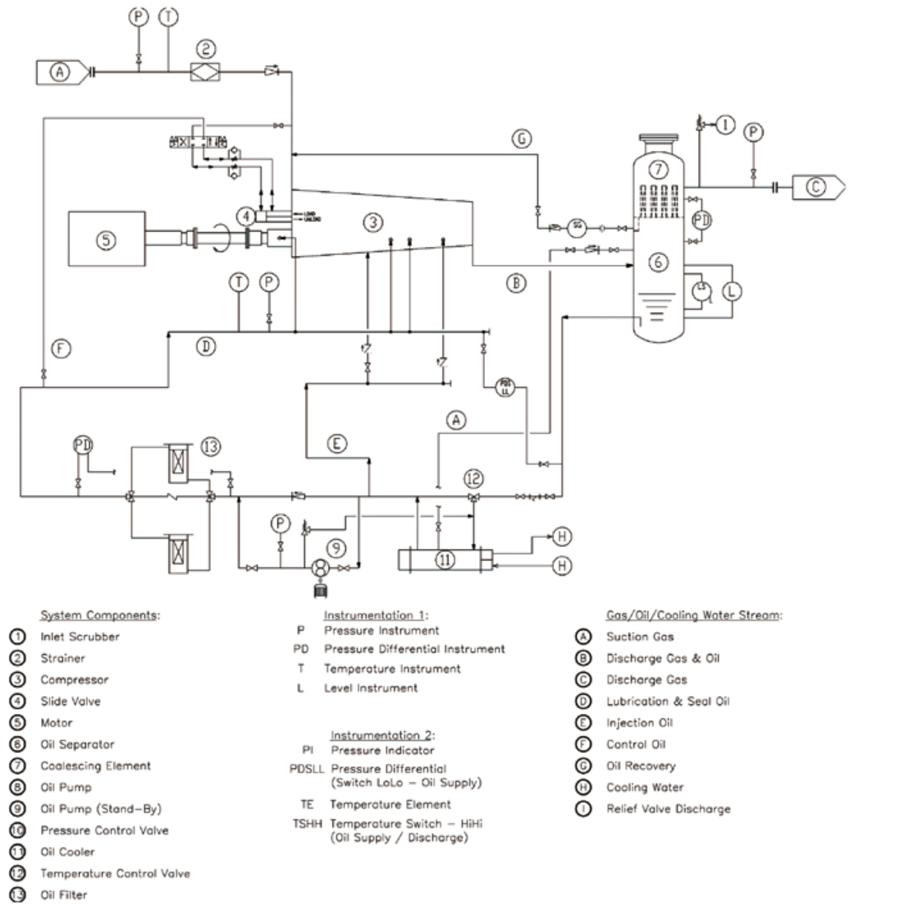

Figure 9. Schematic diagram for an oil injected screw gas compressor.

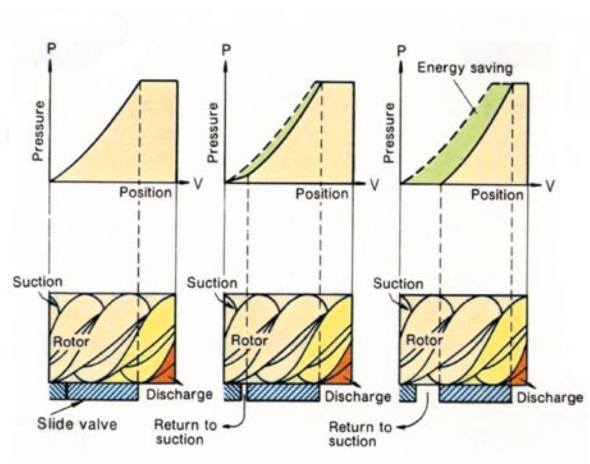

Figure 10. Basic principle of the slide valve mechanism.

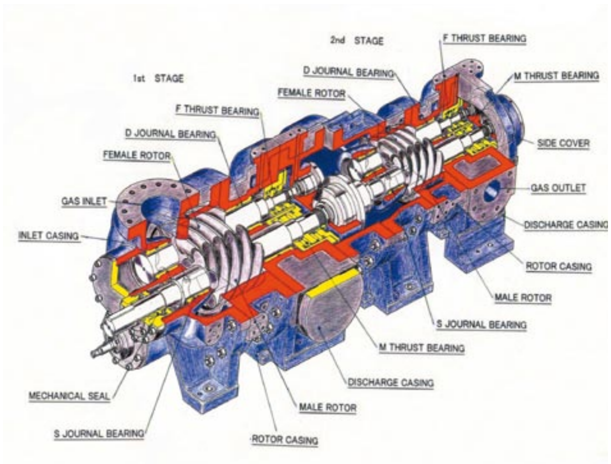

Figure 11. Cutaway drawing of a tandem arrangement oil injected screw gas compressor.