There is a growing trend among many major power consumers including heavy industries, local utilities and capital ventures to favour the utilisation of recoverable energy, which has not been efficiently or effectively utilised in the past. The higher prices expected for oil, gas and power, combined with new economic and political conditions and incentives favour the use of a wide variety of waste gases like refinery off gas, syngas, landfill gas, ladle gas, and biogas. Previously wasted gases can now be utilised more efficiently, saving the project owners a potentially huge amount of money. The realisation of these projects is influenced by many factors like governmental policies and the market prices of oil and gas. However, this trend is surely expanding, since environmental regulations are getting strict, and the prices of oil and gas are predicted to trend upward over time.

One of the best methods to utilise wasted gases is as fuel gas for combined heat and power (CHP) with gas turbines. Also, the process to utilise syngas or biogas as the basic resource of ethanol production is being developed. However, these wasted gases have difficult characteristics to handle by conventional reciprocating type or centrifugal type compressors, as:

- High compression ratio is required.
- Gas condition is not steady.
- Turn down operation is often required.

Especially, these gases are required to be pressurised from close to atmospheric pressure up to middle or high pressures by gas compressors. The API 619 screw gas compressor is the most suitable compressor design for the above mentioned applications, because of the following reasons.

- Capable of a high compression ratio with a single stage.
- Capable of flexible operations such as gas composition, temperature and pressure change.
- Easy and reliable turn down by slide valve unloader.
- Lower maintenance costs because of fewer parts requiring maintenance such as one seal per compressor.

Refinery off gas, syngas, landfill gas, ladle gas, and biogas are abundant at low pressure. Screw compressors can be utilised to compress these otherwise wasted gases up to the higher pressures where they can be used as a valuable fuel source, feeding various types of gas turbines. Meanwhile, some applications like ethanol production require various types of compressors. Figure 1 shows the applicable range of Kobelco process gas compressors for API617 Centrifugal, API618 Reciprocating and API619 Screw. A centrifugal type is suitable for larger volume applications and, reciprocating type is suitable for higher pressure applications. The optimised combination of each type of compressor increases both reliability and efficiency of the process. Among each type of compressor the screw compressor has many advantages.
looks at API619 screw gas compressors for recoverable energy projects.
and as a result, the screw compressor is now the best fit in various applications, where centrifugal and reciprocating types were utilised before. This article shows these unique and useful mechanical features of the API619 screw gas compressor when used in recoverable energy applications.

Structure of screw compressor
Figure 2 shows a typical oil injected screw gas compressor cutaway. There are two rotors inside the casing. A male rotor and a female rotor, both in contact with each other along the lobe surface, and aided by an oil film. Oil is supplied directly into the rotor chamber to serve as the oil film lubricant as well as for lubrication to the rotor bearings and seal. Therefore, the oil in the rotor chamber serves as a lubricant, a coolant and also a sealant. The male rotor is directly driven by and coupled to either a 2-pole or 4-pole electric motor driver. The male rotor then drives the female rotor. An external gear unit is normally not required, since the tip speed of the oil injected screw gas compressor is in its design range when operating at the 2-pole or 4-pole motor speed. Because oil is injected into the rotor chamber where it serves as a bearing lubricant, a shaft seal between the rotor and the bearing is not necessary. The oil injected screw compressor only has one mechanical seal, which is located at the outboard drive shaft end of the compressor. The compressor utilises a sleeve type journal bearing on the end of each rotor, and the thrust bearings are typically tilting pad design, and are located outboard of the sleeve type journal bearings. The process gas and lubrication oil mixture is discharged from the compressor discharge nozzle directly into an on-skyd, high efficiency oil separation system, where the oil is removed from the process gas. Oil is separated from the process gas via the oil separation system, and the oil is then reinjected into the compressor lubrication circuit. A feature unique to oil injected screw compressors is a built in slide valve mechanism located just beneath the rotors.

The slide valve serves as an unloader and the gas flow rate can be varied, providing a very wide turn down ratio during operation with significant savings in power during turndown. Details of the slide valve mechanism are described below.

Since the oil acts as both coolant and sealant, the allowable compression ratio by single stage is extremely high. Discharge temperature can be adjusted by oil flow rate. Oil injected into the rotor chamber can absorb the compression heat generated in the compressor. When a very high pressure ratio is required, a tandem arrangement of two stage compressors combined in one casing can be employed to achieve better efficiency (Figure 3). Typically, this tandem arrangement is used when pressure ratio exceeds 8:1, and can be applied to a ratio of more than 50:1. It is important to note that there is no external inter cooler and piping required for the intermediate stage, since the oil acts as the coolant.

As mentioned above, recoverable waste gases such as refinery off gas, syngas, landfill gas, ladle gas, and biogas are often more abundant at low pressures. Reciprocating type or centrifugal type compressors require multiple stages to achieve the high pressure ratio, resulting in lower reliability and higher initial cost. A screw compressor is much more suitable for these high ratio applications. For example, Figure 4a shows a screw compressor package for a fuel gas booster application, which utilises refinery off gas. The inlet gas pressure is 86 psig, and final gas discharge pressure is 690 psig to meet the fuel pressure requirement of a GE LM6000 gas turbine. Figure 4b shows another screw compressor package for syngas booster pressurising syngas from 53 psig up to 423 psig. For both cases, single stage screw compressors achieve approximately 8:1 pressure ratio. In either a reciprocating compressor or a centrifugal compressor, at least two stages of compression would be required.

Principle of compression
The principle of compression of a screw compressor is positive displacement, which is the same as a reciprocating compressor (Figure 5). Normally, the gas composition of refinery off gas, syngas, landfill gas, ladle gas, biogas is not steady due to these resources. Therefore, a centrifugal compressor, which utilises dynamic and kinetic energy, is not a good fit. Any change of the gas molecular weight will incur a drastic impact on the performance of the impeller, plus, surge points can be affected. On the other hand, a screw compressor easily adapts to handle variable and changeable gas compositions without any concern because of positive displacement compression.
Unique power saving feature

With the built-in slide valve, oil injected screw compressors have an inherently wide and smooth turndown range (100% down to 15%) with power savings. Additional turndown via recycle or spillback is additionally only required from 15% down to 0%. The slide valve serves as an unloader to adjust the inlet volume of the compressor. During turndown operation, this equates to a significant amount of power savings. The slide valve is located just beneath the rotors and moves parallel to the rotors in an axial direction, typically actuated by a hydraulic cylinder, which uses pressurised oil from the compressor lube oil line. When the slide valve is automatically moved towards the suction side of the compressor, the compressor operates fully loaded. The compressor starts to unload when the slide valve is moved towards the discharge port. During full load operation, the entire length of the rotor is utilised and the inlet volume of the compressor is maximised. During turndown operation, the slide valve is moved towards the discharge side, linearly unloading the compressor. The effective length of the compression chamber is thus shortened. The resulting inlet volume of the compressor is thus reduced. The resultant power savings are realised during turndown operation, because compression is being performed with a lower inlet volume, therefore the theoretical brake horsepower is reduced (Figure 6).

By comparison, a reciprocating compressor uses a step turndown, i.e. (100%, 75%, 50%, 25%) and a centrifugal compressor has limited turndown via a bypass, or typically only from 100% to 70%, if fitted with an inlet guide vane assembly. The wider turndown range of the screw compressor provides for extremely flexible operation, with significant power savings in a heavy duty, robust design. Because recoverable energy applications eventually require accurate and flexible turndown due to changeable gas compositions,
the screw compressor with slide valve system offers a huge benefit to the plant owners.

High pressure and heavy duty application

A few decades ago, screw compressors that did not comply with API standards were mainly used in lower pressure applications such as instrument air, and refrigeration services. Now, many API619 screw compressors are used for process gas applications and are frequently utilised for heavy duty applications. For instance, in refineries, these heavy duty applications include hydrogen recycle gas for gasoline desulfurisation, as well as for hydrogen booster services. These are the areas where API618 reciprocating and API617 centrifugal compressors were originally utilised, but are now being replaced by API619 screw compressors. Such transitions have been achieved by extending advantages of the screw compressors and continuous technical progress of the key elements such as the rotor profile, the seal and the bearings. As of today, Kobelco oil injected screw gas compressors can achieve discharge pressures up to 100 barG (=1500 psiG). Kobelco has already delivered screw gas compressors designed for 70 barg (1000 psig) on several projects (Figure 7). Gas compressors for recoverable energy applications require a heavy duty design, capable of handling high compression ratio, higher discharge pressures, and have to be able to handle fluctuating gas compositions with molecular weight change easily. API619 screw compressors definitely provide these capabilities on the basis of many successful experiences in heavy duty refinery and petrochemical applications.

Conclusion

The chance to utilise a wide choice of waste gases for recoverable energy projects is increasing rapidly. A screw compressor is extremely suitable for these applications due to the ability to handle high compression ratios by single stage or tandem stage; the flexibility to handle a wide range of variable and changeable gas compositions; and the stability, plus a wide turndown range with power saving. The API 619 screw compressor contributes to the global needs to utilise recoverable energy in a more efficient way.