Integral to success

Daniel Potter, Ingersoll Rand, USA, looks at gas-turbine-driven integrally geared centrifugal compressors for small scale LNG refrigeration.

The development of new techniques to extract natural gas that has previously been trapped in unmarketable reserves has both helped to provide access to an abundant domestic supply, and led to favourable pricing in the US. This new capacity is fuelling development of uses for the newly available resources, such as natural gas-fired power generation and fleet vehicle fuelling projects. To help transmit the expanded supply, LNG peak shaving infrastructure is being added or expanded to gas pipeline networks. These peak shaving plants were originally constructed to store fuel capacity to supplement pipeline supply during seasonal demand spikes for heating gas, and are now increasingly used to provide a reliable source of fuel for gas-fired, electrical power production, as well as LNG-powered vehicle fleets. The peak shaving concept requires a refrigeration loop to cool and liquefy the natural gas for storage, which is driven at its core by the main refrigerant compressor. Integrally geared centrifugal (IGC) compressors have proven to be a dependable choice for the main refrigerant compressor for many small scale LNG processes and have demonstrated reliable service with a variety of refrigerants, such as nitrogen and mixed hydrocarbons. Now that LNG peak shaving facilities are being constructed in increasingly undeveloped locations, IGC manufacturers must take into account new design challenges presented by the nuances of these circumstances, most notably how to power the compressor driver and how to maintain a secure gas sealing system.

Process gas compression technology

IGC compression technology was originally developed in the late 1940s and has a rich history of being instrumental to gas processing applications. Since its debut over 65 years ago, IGC compression technology has evolved to handle higher pressures and flows in a compact and highly efficient package. Through this progression, and the associated recognition from the American Petroleum Institute (API), IGC compressors now see significant market penetration and have become the dependable solution that many industries look to for their compression needs.[1, 2]

IGCs are well-suited and adaptable to the varying process conditions for gas compression applications. The compressor utilises a large, helical-cut bullgear driven at low speeds to drive multiple pinion gears with overhung impellers (see Figure 1). The integral gear design allows for the rotational velocity of each pinion gear to be designed based on the optimal aerodynamic characteristics of the impeller. The design arrangement of IGCs inherently separates the lubricating oil in the gear casing from the process, ensuring oil-free process gas without the need for additional separation systems. Some original equipment manufacturers (OEMs) employ enhanced measures, such as an atmospheric air gap between the gear casing and compression volutes and/or maintaining the gearbox at vacuum pressure to keep lubricating oil from seeping out of the casing, to further ensure the of delivery oil-free gas.[3]

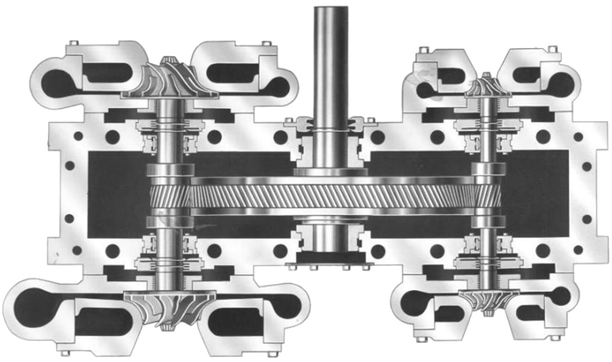

Figure 1. This figure shows the top view of an Ingersoll Rand MSG integrally geared centrifugal (IGC) compressor with cross-section taken at the horizontal split line of the compressor gearbox (the approximate plane at which the input shaft enters the gearbox).

Case study

Ingersoll Rand successfully executed a project for a nitrogen (N_2) recycle compressor to support a 120 000 gal./d liquefaction plant. The plant was installed to provide peak shaving capacity in support of newly tapped natural gas reserves in the US. The company has been producing N_2 recycle compressors since 1971 and has accumulated hundreds of reference installations for IGC compressors in this particular service. Most references are for applications in air separation plants, but the core compressor design philosophy remains very similar for small scale LNG plants. However, due to the lack of substantial electrical power infrastructure at the location of the peak shaving facility in this case, a suitable supply of power for an electric drive motor was not available, and a lack of N_2 generating capability onsite necessitated an enhanced sealing system to prevent leakage of the N_2 refrigerant gas. To satisfy the demand for an efficient main refrigerant compressor that the operator could trust to operate reliably and economically, Ingersoll Rand provided

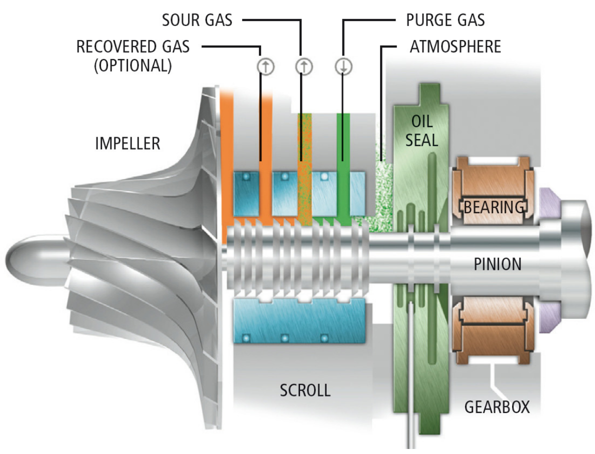

Figure 2. Multiport babbitted seal with purge.

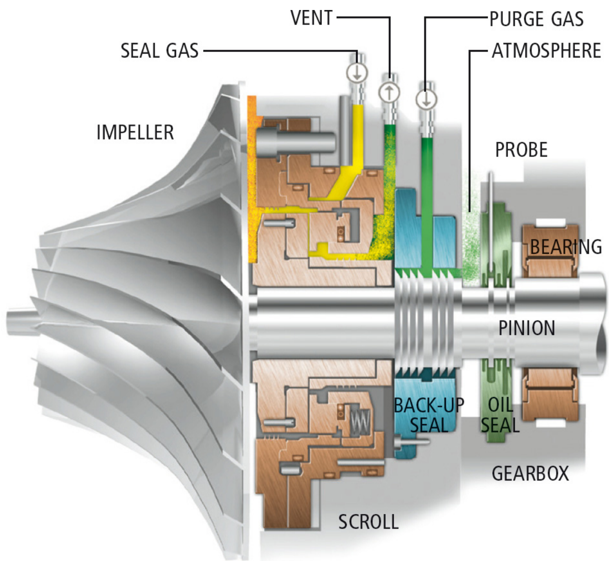

Figure 3. Single dry-face seal with a babbitted backup.

a custom-engineered MSG® IGC compressor package with a gas-turbine (GT) driver and with a seal gas recovery system.

Gas-turbine drive

Many areas where gas reserves are currently being developed lack sufficient electrical grid infrastructure to power the startup and operation of large, electric motors. This, coupled with the abundance of cheap natural gas available for fuel, is driving end users to demand a gas-turbine-driven compression solution. In recent history, IGCs needed for many current peak shaving opportunities (approximately 100 000 – 400 000 gal./d) have been designed to be driven by electric motors. This is because electric-drive-motor solutions are typically the least expensive and least complicated in situations where sufficient grid infrastructure is in place. However, in small scale liquefaction applications at newly developed gas reserves, GT solutions are emerging as a preferred choice and presenting new challenges to experienced compressor manufacturers.

Most IGC bullgears are sized for the input speed of an electric motor (1000 – 3600 RPM), but compatible gas

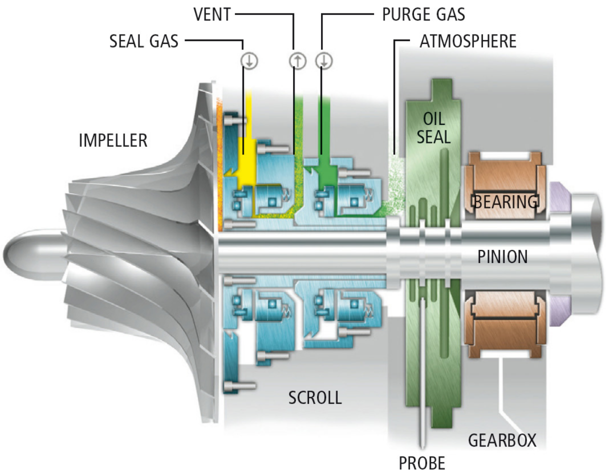

Figure 4. Tandem dry-face seal with integral labyrinth.

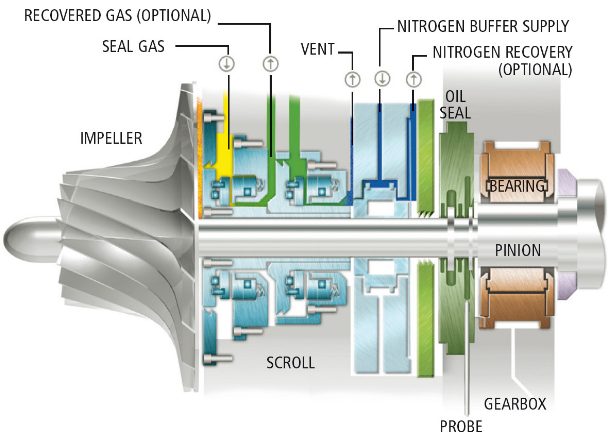

Figure 5. Tandem dry-face seal with carbon ring backup.

turbines typically operate at higher rotational speeds (more than 10 000 RPM). One way of accommodating the increased driver output speed is to incorporate an additional speed-reducing gearbox into the drivetrain. This is a proven, reliable and robust solution that has been applied due to the demonstrated reliability of the train arrangement. However, this peace of mind can come at a price, as the additional gearbox introduces new, parasitic mechanical losses into the system and can increase the required initial capital investment. Although proven, this solution may seem inelegant or redundant, as the IGC is already essentially a compressor integrated with a speed-changing gearbox, hence the description of the technology as 'integrally geared'. Some gearbox manufacturers and compressor OEMs have begun to develop direct-drive solutions where the external speed-reducing gearbox is eliminated from the drivetrain by employing a smaller diameter drive gear that is coupled directly with the GT output shaft. The new drive gear is sized to step down the GT output speed to match the normal design speed of the compressor's bullgear. This allows the compressor OEM to take advantage of existing compressor designs, while repurposing the IGC bullgear into an idler gear that drives the pinions for the compression stages.

IGCs are relatively versatile because the compressor can be driven by electric motor, GT, or by other means, so long as the bullgear, and consequently the pinion gears and impellers, spin at their design speeds. However, with a GT drive, the turbine output speeds during the startup and cool-down cycles must be taken into consideration during compressor design. It is important that the compressor OEM performs a complete drivetrain analysis at these conditions as well, so as to avoid dwelling at a critical speed during the startup and cool-down cycles. The compressor OEM must also maintain good lines of communication with the GT OEM to coordinate this information and incorporate any changes in critical speeds into the drivetrain analysis and design.

In addition to the need for a close relationship between the IGC and GT OEMs for coordination on the drivetrain design, the common demand for single-point responsibility for the complete package (compressor and driver) from most purchasers will necessitate that one of the manufacturers take primary responsibility for the complete solution.[4] In most cases, with typical IGC projects driven by an electric motor, the compressor manufacturer will purchase the drive motor and provide the complete solution to the customer. However, with GT-driven packages, the value of the driver often far exceeds the value of the compressor, so it makes more commercial sense for the GT OEM to take primary responsibility for the package and purchase the compressor from the IGC OEM. This need for close alignment on design and project execution highlights the need for the IGC OEM to develop a close partnership with a GT manufacturer or vice versa.

Sealing

For most N_2 recycle applications, Ingersoll Rand typically provides a babbitted (abradable) labyrinth seal because this technology provides a low rate of leakage without

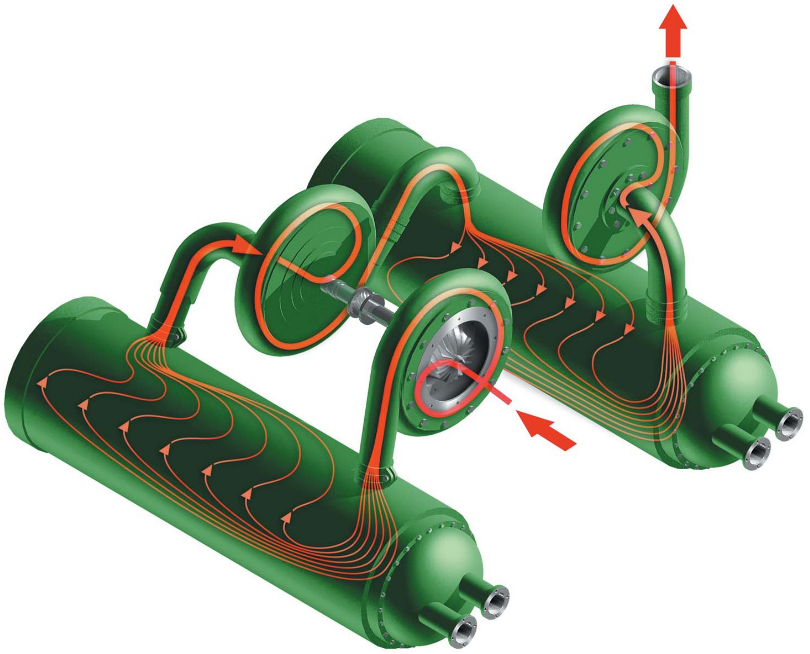

Figure 6. This shows the typical process gas flow path for a three-stage Ingersoll Rand MSG IGC compressor with intercoolers (the gearbox has been excluded from this illustration to provide an unobstructed view of the flow path).

the additional cost of more complex sealing systems with recovery options. As mentioned previously, the majority of these installations are at air separation plants where N_2 is being produced on site, so a small amount of leakage may be tolerable because part of the plant production can feed the N_2 refrigeration cycle to make up for the small portion of the gas that is lost to the atmosphere through the seals. However, when applying machines in remote sites where N_2 is not being produced on site, it may be more favourable for the end-user to select a seal system design that is initially more expensive to include gas recovery provisions with the intent of reducing the overall operating cost of the machinery. Enhanced solutions, such as a buffered and educted, babbited labyrinth seal (see Figure 2), and even more complex single and tandem dry-face seal designs with backup seals (see Figures 3, 4 and 5), can help reduce the overall cost of ownership by decreasing the need for the potentially high expense of frequent, trucked-in deliveries of N_2 or other costly refrigerants, such as mixed hydrocarbons, to replace gas that has leaked through the seals.

Air separation connection

Many companies now offering engineering, procurement, and construction (EPC) – and sometimes operational – services for LNG liquefaction plants and processes have gained their expertise in gas refrigeration and liquefaction in the air separation industry. IGC compressors have been widely adopted and have followed an interconnected development path with the air separation industry. Several benefits offered by the technology align with the operating requirements of process applications. These advantages include the following:

- The ability to deliver large volumes of process gas to feed downstream equipment continuously at constant pressure without the pulsations that are typical of positive displacement technology, such as rotary screw or reciprocating compressors.
- The ability to tune, through pinion speed optimisation, each compression stage for optimal aerodynamic efficiency, unlike a single-shaft centrifugal compressor where all stages must spin at the same speed as the main shaft.
- The ability to accommodate multiple gas processes in a single machine, such as N_2 feed and recycle services.
- The ability of IGC technology to easily accommodate intercooling between compression stages to remove the heat of compression and achieve high isothermal efficiency (see Figure 6).

Conclusion

IGC compressors have a long history of application for refrigeration service, and have been widely accepted by air separation plant engineering houses as the preferred technology for these applications. These same air separation plant EPCs and process owners are now applying their knowledge and experience with gas refrigeration and liquefaction to LNG plants. Their familiarity and trust in IGC technology, combined with the acceptance of IGCs in AP1 617, is helping to make IGCs the preferred technological solution for the main refrigerant compressor in small scale LNG plants. As continued development of newly available gas resources feeds demand for peak shaving and small scale LNG plants in undeveloped locations, IGC manufacturers are adapting their existing, proven designs to accommodate the nuances presented by these circumstances to ensure economical and reliable operation. **LNG**

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