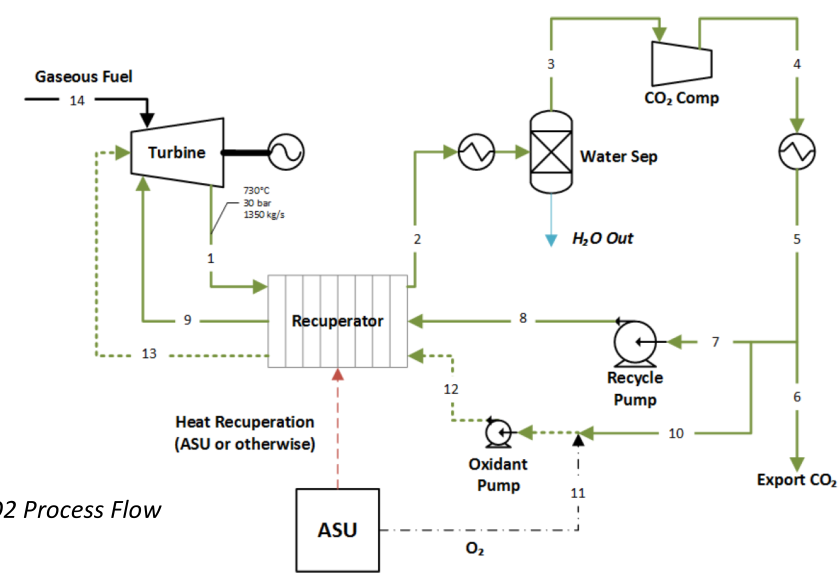
Looking for a more sustainable future with CO_2 & IGCs

The possibilities for using CO_2 in a more sustainable, future world are very promising. However, using CO_2 in industrial processes has actually long been established. In recent decades, key research and development successes have meant that its use has been extended to a number of applications – for example, when high temperatures and pressures are at play, and CO_2 reaches supercritical levels. CO_2 applications nowadays range from its use in the hydrocarbon processing sector to power generation industry, or even food production. In many of the underlying production processes compressors play an integral role.

A closer look at current CO_2 applications

Atlas Copco Gas and Process has long and wide-ranging experience in designing and building compressors for all manner of processes in which CO_2 is used. A prime example very recently is in supercritical CO_2 power recovery, based on the Allam Cycle. This game-changing technology, which makes use of oxyfuel combustion, is being used for highly efficient and green power generation, with plants now entering commercialization. As a result, according to analysts, sCO2 power recovery figures to be one key component in the future global energy mix as the world attempts to transition to net zero emissions by 2050.

Supercritical CO_2 is carbon dioxide that is maintained beyond its supercritical conditions of 87.98 °F and 1071 psi, at which juncture it has properties of both gas and liquid. At this point, even small temperature or pressure changes have a huge impact on density of the CO_2. The result is that instead of the usual phase changes, in this form the process can recover significant energy – and it does this with much smaller compressor equipment and footprint compared to conventional technology.



Allam Cycle sCO2 Process Flow

A second area in which Atlas Copco Gas and Process turbocompressors work with CO_2 is in the production of urea-based fertilizer. When pressured to 140-200 bar, it substantially increases the conversion of ammonia and CO_2, which in turn produces urea. The high levels of efficiency and reliability of the compressor is again a vital factor in the process, which is a principal why specially designed integrally geared compressors are employed. Lower power needs and ease of maintenance of such compressors are further examples of the advantages they bring.

Thirdly, CO_2 is playing an increasingly vital role in enhanced oil recovery in oil fields across the world. The process works by pumping high-pressure CO_2 into an oil reservoir. Supercritical CO_2 is central to a process labelled "miscibility", whereby, the critical temperature and pressure forces the CO_2 to mix with the oil. The substance can then flow, it is collected and under further CO_2 pressure is separated.

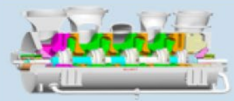
A final example of CO_2 use is in capturing and storing CO_2 released from the burning of environment-damaging fossil fuels. The crux of this process is that after fossil-fuel combustion, the addition of a chemical solvent enables the removal of CO_2, at which point it can be captured and stored. A more established process is to capture CO2 with oxyfuel and precombustion technologies. It is then injected at high pressure into underground reservoirs for later use, in further processes, such as fertilizer production. Over the years, Atlas Copco Gas and Process has developed highly efficient integrally geared centrifugal compressors for both processes in this field.

Integrally geared technology and the challenges of CO_2

Traditionally, the preferred option for CO_2 processes has been to use an in-line centrifugal compressor driven by an electric motor, or a gas or steam turbine (with reciprocating compressors also being used for some CO_2 applications). Depending on the process requirement, other compression methods also provide a good solution and generally function well. As we will show below, however, there are technological and process-led disadvantages, most obviously related to capex considerations, due to the fact in-line versions require more impellers, and they subsequently have a larger footprint. In-line compressors are also more complex to assemble and more difficult to maintain. Just as important is that the system has a reduced level of flexibility, highlighted by the fact that components are mounted on a single shaft, which limits their size depending on the gear driver speed.

Atlas Copco Gas and Process integrally geared compressors (IGC) address many of the process challenges presented by CO_2. IGCs have now been employed for several decades in chemical and petrochemical processes, initially in low- and medium-pressure applications. More recently, however, they have also become well established in high-pressure CO_2 compression at pressures of between 100 and 200 bar, and above.

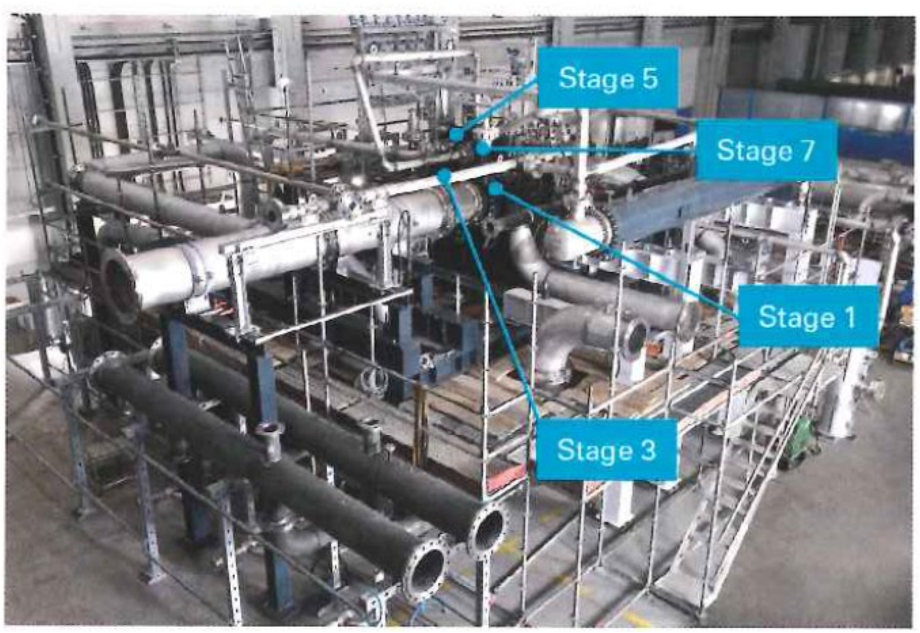
Comparison summary based on same process condition

	Atlas Copco Integrally Geared	Barrel Type (Single Shaft or Inline)
		
Size (L x W x H) m	2.5 x 3.5 x 3	4 x 3 x 2
Weight (tons)	12 tons	20 tons
Polytropic Efficiency %	80%	78%
Installation Cost Factor* (% of Compressor Cost)	50%	70%
Annual Compressor Maintenance Cost Factor** (% of Compressor Cost)	0.8%	1%
No. Of Impellers	4	5 (minimum)

* Based on Real Estate, Crane Capacity and Time, Labor etc.
** Based on Oil Consumption, Rotor Wear (Performance Degradation) and Replacement

Greater velocity, fewer impellers

Integrally geared technology is a well-established, highly efficient and reliable method of compressing CO_2. There are several reasons why integrally geared compressors work so well with CO_2 compression, notably the possibility they provide to adapt the rotor speed in one or more pair of stages (with inter-stage cooling), which provides increased efficiency. Indeed, research shows that the power consumption when using an eight-stage integrally geared compressor in high-pressure applications is around 23% lower than for a 12-stage single shaft machine.



8-stage integrally geared compressor in package assembly

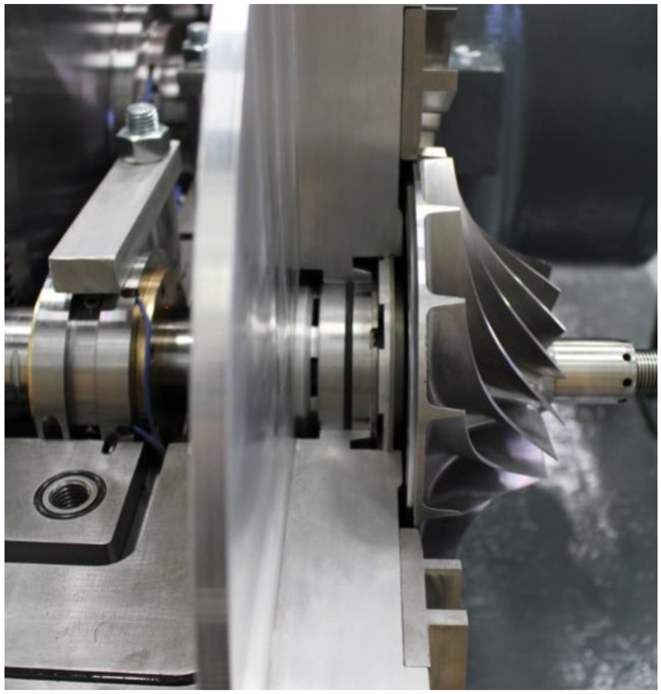
In contrast to in-line compressors, it is advantageous that the IGC combines the gearbox, lube oil system and all the compression stages onto a single skid unit. Similarly, the use of specially designed carbon ring seals, dry gas seals and the seal support systems are also key factors in ensuring integrally geared machines work well with CO_2. IGCs are designed so that stages can be selected independent of the optimum driver speed. Because in-line machines have impellers mounted on the same rotor, velocity is to a high degree determined by the rotor's capability and tip speed. Meanwhile, IGCs provide greater velocity at the same time as requiring fewer impellers. Also, each impeller on an integrally geared compressor can run at its own optimal speed. The benefit of fewer impellers is seen not just in terms of efficiency and performance, but it is also seen in a lower footprint and lower capex.

A key factor in IGC technology is that every impeller in effect becomes its own stage and has its own casing, with its own inlet and discharge connections. Moreover, IG compressors are designed to have intercooling between stages, with a concomitant increased flexibility and more efficient compression. In addition, the arrangement can incorporate incoming or outgoing side streams, while a single compressor also has the ability to deal with multiple gases (no need for separate compressors). Not only that, it is also possible to have both an expander and a compressor mounted on the same gearbox (in an integrally geared Compander set up).

IG compressor flexibility is increased when one considers the nozzle set-ups for both compressor types. In-line compressors have fixed nozzle locations, which limits them to operating within their first and second critical speeds. This is not the case with IG compressors: complementing the advantage of each impeller running at its own optimal speed is the fact that the IG compressor casings can be rotated in order to make the nozzles face in the right direction.

Seals are critical

Atlas Copco also has significant experience in one of the highly critical components of rotating machinery: the seal and seal support system. In fact, in 1975 Atlas Copco became the first company in the world to implement Type 28 dry gas seals in integrally geared compressors. With a demanding and challenging gas such as CO_2, it is of critical importance that leakages are kept to an absolute minimum. Dry gas seals are the outstanding solution when working with CO_2, though in some cases process temperatures can approach a seal's tolerance limit. For this reason, a seal gas cooler can be used to maintain an optimal temperature for the dry gas seal.



Dry gas seals

Conclusion

Integrally geared compressors provide many of the answers to many of the questions posed by working with the challenging properties of CO_2. With their single-skid designs, IGCs lower capex and have smaller footprints. Their lube oil and seal solutions are major factors in their proven high efficiency and reliability, and they have the capability to provide greater power with fewer impellers.

CO_2 is an essential element in energy production and in the entire hydrocarbon value chain. This is the case now and it is going to be the same in the near future, including in the all-important demand for more sustainable power generation, carbon capture, utilization and storage. CO_2 is also increasingly used in feedstock for fertilizers, fuel refining and plastics, as well as in metallurgy, and the production of steel, food and glass. An increasing demand for CO_2 applications means that there will be a likewise increased demand for compressor technology.