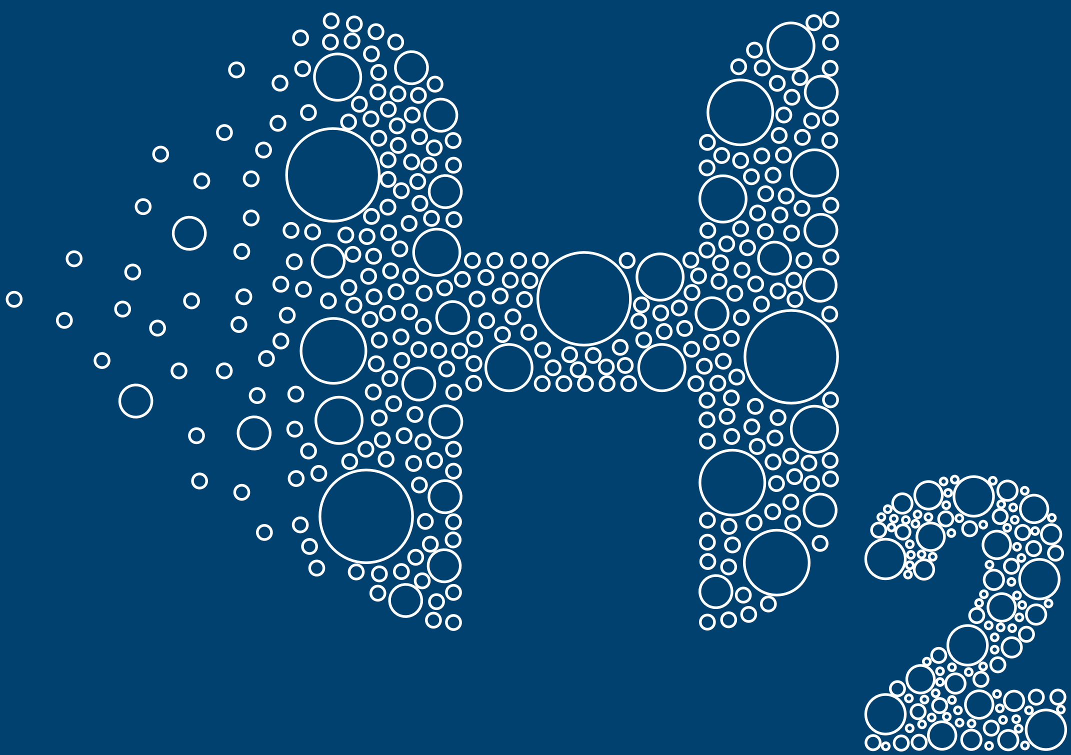
WHITEPAPER

HYDROGEN COMPRESSION WITH SCREW COMPRESSORS



AERZEN

THE MOLECULE OF THE ENERGY TRANSITION

The breakthrough of hydrogen as the central energy carrier of the 21st century is in full swing. More and more countries are working conscientiously to shape a new, climate-friendly hydrogen economy and are adopting national strategies for decarbonisation and the associated sector coupling.

> The number of power-to-gas projects in Germany continues to grow steadily.

The supply and coupling of the industrial sectors of chemicals, petrochemicals and steel, as well as fuel production, will drive the development of production and transport capacities on a massive scale throughout the 2020s. Considerable new storage capacity, as well as import structures for gaseous and liquid hydrogen are either at the advanced planning stage or are already being implemented. Existing distribution networks and pipelines are about to be expanded and involve both cross-border and cross-industry cooperation projects. Modern electrolysers for hydrogen production are currently scaling up from the one- to the two- and three-digit megawatt range. The number of power-to-gas projects in Germany continues to grow steadily.

About three quarters of all matter consists of hydrogen atoms. As the smallest (and thus lightest) molecule, gaseous H2 occupies a particularly large volume and is extremely volatile. However, the flammable and slightly explosive gas can release a lot of energy without producing greenhouse gases. That is why it is so valuable compared to fossil fuels. One kilogram of H2 contains 2.8 times as much energy as one kilogram of petrol.

Efficient and safe compression using different types of compressors makes it possible to provide the required volumes and pressures for industrial applications in an economical way. In addition to classic reciprocating and diaphragm compressors for pressures in the three-digit bar range, screw compressors in particular have their legitimation and economic advantages in the low-pressure range, especially with increasing volume flows and fluctuating operating conditions.

WET HYDROGEN GAS FROM WATER ELECTROLYSIS

Various natural sources are available to produce hydrogen on a large industrial scale. Up to now, natural gas and coal have dominated as hydrogen carriers, but in the future the share of water will grow strongly. Electrolysers split water with the aid of electricity and deliver around 200 Nm^3/h H2 (equivalent to approx. 18 kg/h) and 100 Nm^3/h O2 per megawatt of input power. Depending on the type of electrolyte, or whether it is solid or liquid electrolyte, 0.01 to 0.5 vol.% of the respective other molecule remains, as well as a temperature-dependent water loading of up to 60% in the saturated H2, or O2 mass flow.

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For compressor manufacturers, this means that this water content is also compressed or, to a large extent, separated by pre-drying (e.g. refrigeration drying). Depending on the application of the (end) consumer, different degrees of purity of the H2 gas are required. For the highest requirements, e.g. 5.0 for fuel cells, so-called de-oxo dryers have proven themselves, whose functions lie in the minimisation of oxygen and moisture. After pre-compression, these de-oxo systems can be designed to be correspondingly small and thus cost-optimised. For other hydrogen consuming processes such as iron ore reduction, the production of certain basic chemicals or also for feeding into natural gas networks, the tolerances and limit values with regard to foreign components in the H2 gas are in some cases significantly higher, which simplifies the overall process in terms of process technology and thus reduces costs. From an economic and operational perspective, it is therefore always advisable to have a technology-open, application-oriented process concept in which the needs and scope of supply of the process participants can be optimally complemented.

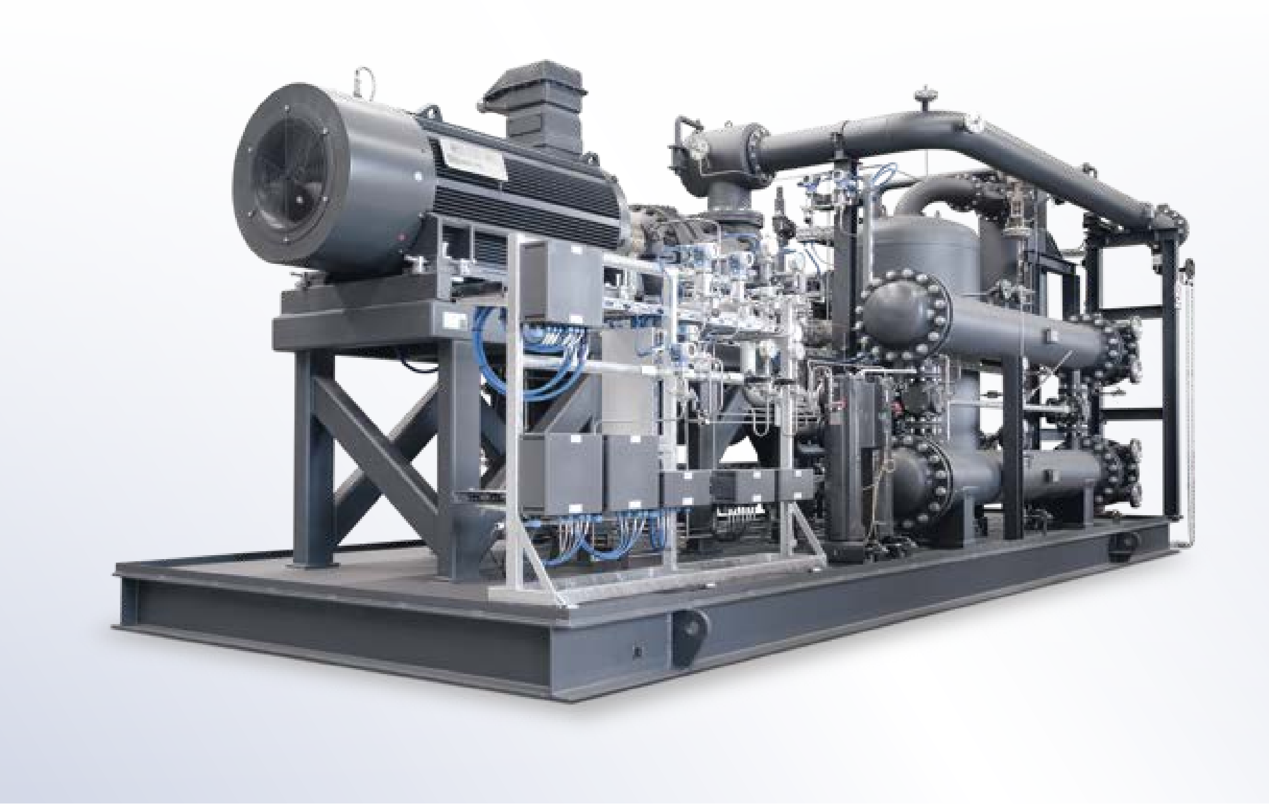
SCREW TECHNOLOGY - VERSATILE AND RELIABLE

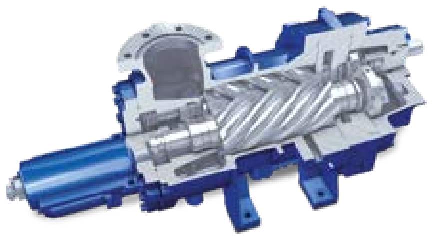
The insensitivity to fluctuation operating conditions and low-pulsation compression behaviour make screws flexible and reliable allrounders.

Rotating positive displacement compressors such as the screw compressor proved their worth in demanding gas applications as early as the second half of the 20th century and have since established themselves. In particular, their insensitivity to fluctuating operating conditions and their design-related internal compression without free mass forces make screws flexible endurance runners with the lowest maintenance intensity and comparatively low operating costs in full and partial load operation.

The principle of operation is based on a main rotor and a secondary rotor which, by continuous rotation, include gas portions from the so-called suction side and discharge them against a smaller outlet geometry on the so-called discharge side. While the main rotor usually takes over the function of the drive, the task of the secondary rotor is the chamber formation and sealing.

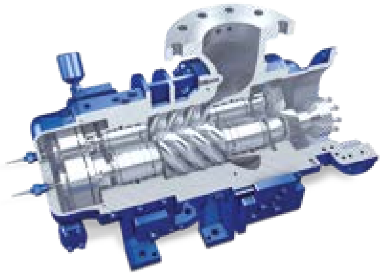
Basically, screws can be divided into oil-free and oil-flooded compressing machine types. Both are used in single or multi-stage concepts in hydrogen applications; however, in different working ranges due to their design (concerns circumferential speed of the rotors, differential pressure, delivery volumes). The following figures illustrate the main differences and show the work areas in relation to each other:





Oil flooded:

- Entire interior under oil, thus compact design with smaller bearing distances
- Driven main rotor rolls directly onto the rotating secondary rotor (oil lubrication film must not tear)
- Highest differential pressures and bearing loads
- Lower circumferential speed and volumes
- Wet gas must be compressed above the dew point (avoidance of water condensation into the oil)
- Pre-drying makes sense with regard to operating costs and service life of the oil
- Version with oil lubricated slide valve (regulation of the volume flow at constant speed and constant final pressure; acts as an internal bypass and can also be used as a start-up unloader)



Oil-free (water-injected):

- Conveying chamber 100% oil-free; with water injection for cooling and gap sealing
- Driven main rotor without contact to the secondary rotor; synchronisation via gear pair
- Higher circumferential speed and volumes
- Oil chambers separated by separating seals and so-called neutral chambers, resulting in larger bearing distances
- Lower differential pressures and bearing loads
- Wet gas does not have to be compressed above the dew point
- Pre-drying, dew points not relevant

Oil-free (dry):

- Conveying chamber 100% oil-free, but sealing medium enters the conveying chamber
- Driven male rotor without contact to female rotor; synchronisation via gear pair
- Differential pressures limited by maximum temperature development or discharge temperature (no internal cooling medium)
- Gas or liquid-locked seals at the conveying chamber (own medium as sealing gas also possible)
- Maximum circumferential speed and volumes
- Wet gas does not have to be compressed above the dew point

For all types it is possible to control the volume flow via the speed with the aid of a frequency converter. At constant torque, load changes of about 1 Hz/s are standard over the entire control range. The type of radial bearing compromises maximum forces with minimum speed and therefore volum flow control range. AERZEN combines roller element or sleeve type bearing to enbale best technoeconomic solution for given application cases.

In principle, delivery and efficiency rates rise with the increasing sealing or minimisation of the internal gaps between rotors, housing and bearings (as well as between rotors and control slides in the case of oil-flooded machines with control slide). The higher the differential pressure and the lower the gas density, the higher the gap losses. The injection of a fluid (oil, water) is therefore not only for cooling purpose, but always also for gap sealing.

With the lower temperature difference due to the injection medium, the isentropic compression tends to shift to isothermal compression, in other words, there is a change of state in the PV diagram. The associated technical labour savings benefit the specific energy requirement and thus the overall efficiency.

The wet oxygen produced during water electrolysis is also to be reused - AERZEN booster blowers are ideal for this purpose.

TECHNOLOGY SELECTION BASED ON APPLICATION

Process and product requirements vary widely by application and end user in terms of required purity and reliability ...

The process and product requirements differ greatly depending on the application and end user in terms of required purity and reliability, as well as in the mode of operation and cost sensitivity. The individually critical limit values for the residual contents of water, oxygen and oil aerosols sometimes have a great influence on the acquisition and operating costs and may require the use of oil-free compressors or additional fine separators for oil-flooded machines.

In contrast to other compression technologies, screws can handle high volume flows with comparatively small footprints and lower investment costs. With respect to additional groundwork and building costs, this advantage even further increases. Therefore compact designed screw packages provide best techno-economic solution in low pressure range.

SOLUTIONS MADE BY AERZEN

For decades, AERZEN has been offering both oil-flooded and oil-free compressor series for a wide range of process gases. AERZEN consulting therefore always provides multiple perspectives and benefits from field and service experience of both technologies. AERZEN also consults end users and EPC contractors to optimize downstream transfer points of compression, filter or separation systems.

In addition to screw compressors, AERZEN also supplies Roots-type process gas blowers in various pressure ranges. These can, for example, transport the wet oxygen from water electrolysis to industrial customers such as wastewater treatment plants, cement works or glass producers - all in the service of sector coupling.

All machine types are integrated into fully functional assembly concepts and consistently aligned to the operator's requirement profile. Both standardised and highly customised individual solutions are part of the AERZEN range of services.

Further information can be found in the current brochures or in our customer presentation. Contact us for reference lists and technical documents of typical solution concepts. Please send your request (RFQ) to **processgas@aerzen.com**

FOR MORE INFORMATION ON THESE AND OTHER TOPICS RELATED TO AERZEN PROCESS GAS SOLUTIONS, PLEASE VISIT:
www.aerzen.com

AERZEN. Compression is the key to success.

AERZEN was founded in 1864 as Aerzener Maschinenfabrik. In 1868, we built Europe's first positive displacement blower. The first turbo blowers followed in 1911, the first screw compressors in 1943, and in 2010 the world's first rotary lobe compressor package. Innovations made by AERZEN keep driving forward the development of compressor technology. Today, AERZEN is among the world's longest established and most significant manufacturers of positive displacement blowers, rotary lobe compressors, screw compressors and turbo blowers. AERZEN is among the undisputed market leaders in many areas of application.

At our 50 subsidiaries around the world, more than 2,500 experienced employees are working hard to shape the future of compressor technology. Their technological expertise, our international network of experts, and the constant feedback we get from our customers provide the basis for our success. AERZEN products and services set the standard in terms of reliability, value and efficiency. Challenge us.

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