WHITEPAPER

SUSTAINABLE AND RESOURCE-SAVING PROCESSES IN CEMENT PRODUCTION

AERZEN

AERZEN SOLUTIONS FOR IMPROVEMENT OF PYRO PROCESSING

In 2016, 4.1 billion tonnes of cement were produced worldwide, resulting in CO_2 emissions of around 2.2 billion tonnes (8 % of total global CO_2 production). Since then, the industry has been striving to reduce the harmful effects of its activities on the environment, although the efforts made so far are still far from sufficient.

> Despite the impact of Covid-19 on global markets, the cement industry achieved the same production level as in 2019.

According to the latest report from the International Energy Association (IEA), 4.1 billion tonnes of cement were produced worldwide in 2019 and 2020. That means: Despite the impact of COVID 19 on global markets, the cement industry achieved the same production level as in 2019. This generated 2.17 billion tonnes of CO_2, a reduction of 1.5 % compared to 2016.

The industry has made a commitment to the international community to reduce CO_2 emissions to 0.48 t CO_2 per tonne of cement produced by 2030 - an ambitious target. Estimated cement production will be around 4.8 billion tonnes of cement by 2030, but only 2.3 billion tonnes of CO_2 will be emitted. CO_2 emissions per tonne of cement produced must therefore fall by 5.5 % compared to 2020.

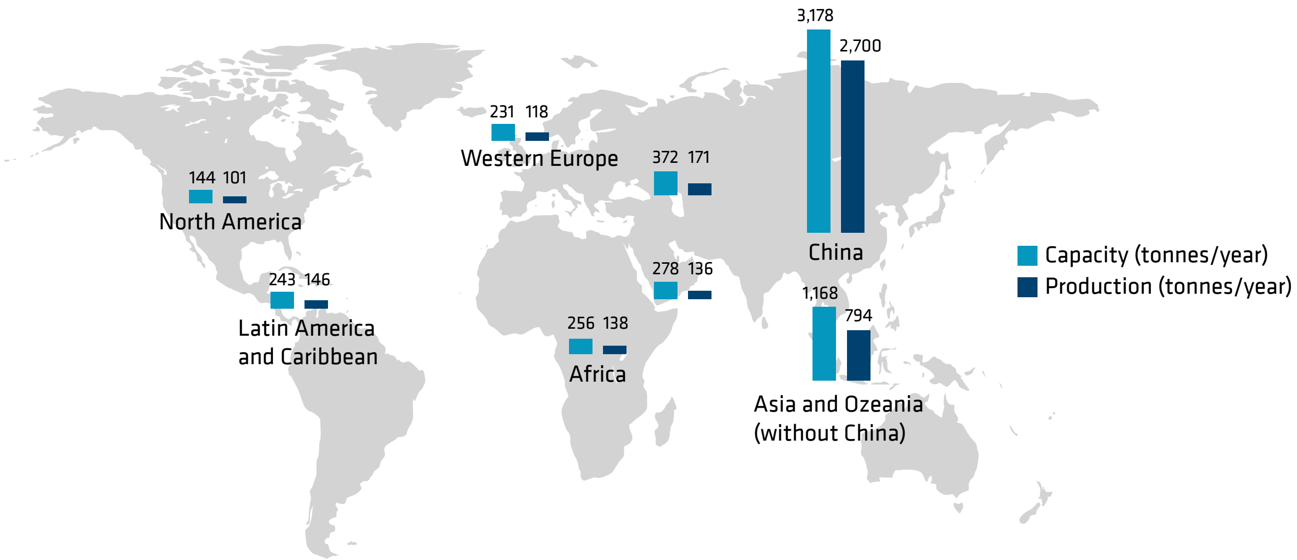
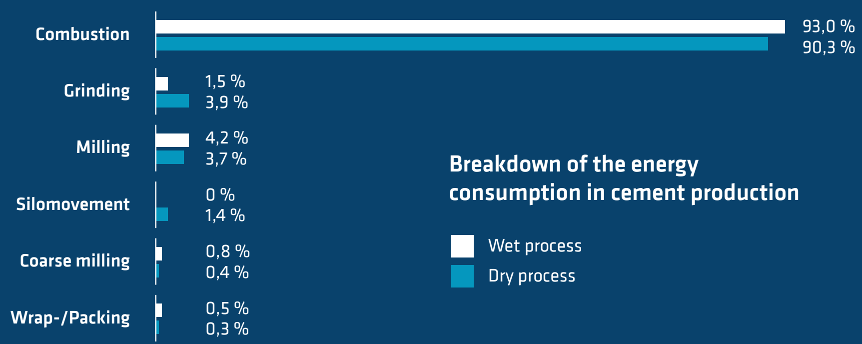


Illustration of the global cement capacity
Source: CW Research 2020

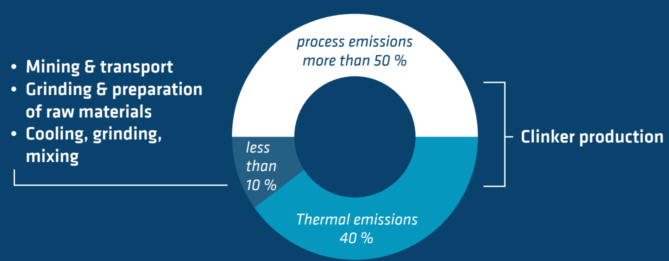
AERZEN is aware of the challenge and is committed to helping achieve the goals for the cement industry..

When breaking down the energy consumption, it is noticeable that the dry cement production process is the most energy-intensive process, as a temperature of up to 1,450 °C must be reached during the calcination process. Most of this is thermal energy, which produces the most CO_2 emissions.



AERZEN is aware of the challenge and is committed to helping achieve the targets for the cement industry. Of the 2.3 billion tonnes of CO_2 produced in the cement industry in 2020, more than 90 % was generated in the calcination process (Fig. 3: Clinker_CO_2). This is of course related to the breakdown of energy consumption in the production process, which takes into account both electrical and thermal consumption.

The production of „clinker“ is responsible for the majority of CO_2 emissions in cement production



Quelle: Chatham House

APPLICATIONS FROM THE FIELD

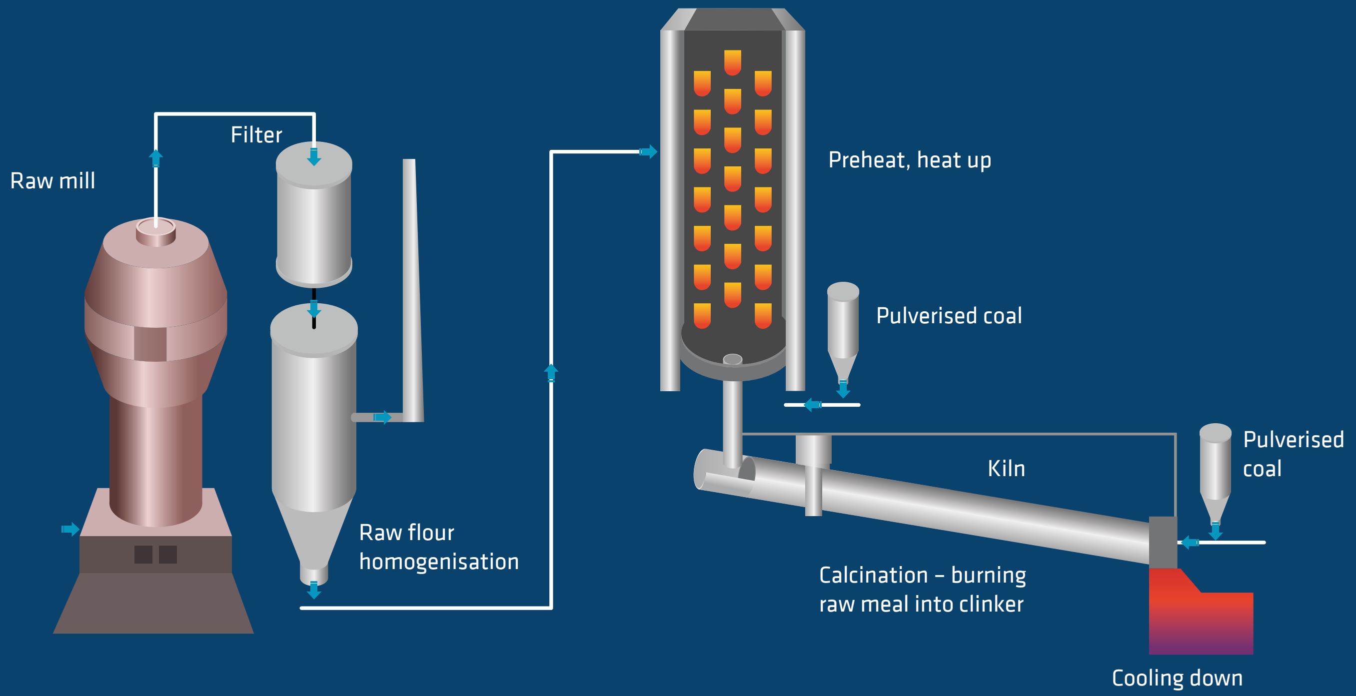
AERZEN has been supporting numerous companies worldwide as a reliable supplier for over 150 years, this also includes the areas of customer service and technology consulting. We build close, strong and trusting collaborations with our customers, which have enabled the AERZEN team to actively participate in many renewal, expansion and optimisation projects over the years.

AERZEN has been supporting renowned cement companies worldwide for over 150 years.

This Whitepaper focuses on three key applications around pyro process optimisation in a conventional cement plant operating under the following conditions:

- Production capacity of the plant: 5.4 Mt/year
- Cement production in 2020: 4.05 Mt/year
- Production overcapacity: 25 %
- Fuel type for thermal energy production: mainly coal (switching to some alternative fuels)
- Firing technology: short kiln with preheater tower and calciner
- Grinding technology for raw materials: vertical mill
- Grinding technology for the finished cement: ball mill

The pyro process



CASE 1: INCREASE OF THE RAW MATERIAL EXTRACTION CAPACITY FROM 2,700 KG/H TO 3,500 KG/H

The cement industry, like almost all other industries, requires a mixture of raw materials to produce the final product: clinker, which is essentially finished cement before the final grinding process. The quality of the raw materials and the correct chemical composition of these materials play a central role in the proper firing process, which should avoid lower heat transfer to batches of poor quality. The raw material is as important as all other process components. It plays a crucial role in the quality of the final product. Cement is produced by a strictly controlled chemical combination (figure 5: raw meal for cement), consisting of calcium, silicon, aluminium, iron and other substances.

The main constituents are calcium oxide and silicon dioxide, mixed with a smaller proportion of aluminium and iron components. The weight percentage of the original mix is tested in the laboratory and must meet the standard classification according to ASTM C1157, in order to receive the designation Portland cement. If there are deviations in the composition, you still get a valid building material, but it cannot be called Portland cement and consequently cannot be used for high-strength concrete applications such as buildings, bridges, roads, etc.. AERZEN is aware of the challenge and is committed to helping achieve the targets for the cement industry. Talking about the 2.3 billion tonnes of CO_2, generated in the cement industry in 2020, over 90 % was generated in the calcination process (figure 3: clinker_CO_2). This is of course related to the breakdown of energy consumption in the production process, which takes into account both electrical and thermal consumption.

Constituents	Range in weight-%
CaO	60-69
SiO_2	18-24
AlO_2	4-8
Fe_2O_3	1-8
MgO	less than 5
K_2O	less than 2

Worldwide, high-performance AERZEN plants homogenise and transport millions of tonnes of raw materials.

All these materials must be mixed properly in the homogenisation silos, so that the final composition is as pure as possible and has the required grain size for the preheater tower. Homogenisation in the silos and pneumatic conveying of the raw materials to the preheater tower are two of the most important applications in a cement plant. Worldwide, high-performance plants from AERZEN homogenise and convey millions of tonnes of raw materials.

The plant presented here operates a total of 10 GM25 S blower packages to homogenise the mixture in three silos with a capacity of 12,000 tonnes. If a rotary vane compressor is used instead of the blowers to pneumatically convey the raw materials into the preheater tower, the operating conditions for these two processes are as follows:

Dense phase flow is used for pneumatic raw material conveying. The conveying capacity is 2,700 kg/h of raw meal at a conveying speed of 16 m/s by means of a piping with a nominal width of DN200 over a length of 250 m. The rotary vane compressor generates a volume flow of 24 m^3/min at a pressure difference of 1,730 mbar. It requires a power of 115 kW for this.

The 2 GM25 S-Delta blowers operated in the homogenisation application, on the other hand, generate a volume flow of 22 m^3/min at a differential pressure of 450 mbar. They have a power consumption of 22.1 kW. These machines have operated trouble-free around the clock for the last 10 years.

Case 1:
The challenge

At the end of 2017, production was increased, so that the raw material input also increased significantly. The smooth operation of the rotary vane compressor requires an extremely high oil volume, a permanent water supply for cooling and an overhaul carried out at least once a year. This is the only way to ensure that the space inside between the sliders and the cylinder remains clear and the efficiency level is maintained. The machine was running close to capacity and optimisation of the machine was not easy to implement. The AERZEN team supported the pre-engineering process and helped with basic calculations for the new pneumatic conveying capacity the system required.

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The real challenge of this project was to increase the conveying capacity from 2,700 kg/h to the maximum capacity, while using the same piping system for the homogenised raw material. The most common conveying method for this type of material and density is the dense flow conveying. This essentially means that the material is transported from one point to the next at a slower speed, generally less than 20 m/s in the tube sheet. The piping diameter posed a particular challenge in this project. Nevertheless, by increasing the flow rate by 50 % and differential pressure by 15 %, we were able to increase the conveying capacity of the piping from 2,700 kg/h to 3,500 kg/h (this is a 30 % increase). The conveying speed decreases and the differential pressure increases to 2,200 mbar, as more material has to be moved through the same piping diameter. The process speed was reduced to 12 m/s, to avoid clogging of the piping due to the additional material in the system.

Important findings from case 1

- Increase in production capacity by almost 30 % with almost the same energy consumption using the same main components such as piping, electrical wiring and footprint. No major structural or mechanical investments. (The feed valve had to be adapted to the new handling capacity.)
- Cost-intensive maintenance on oil tanks and the water supply for cooling as well as complete repairs of the rotary vane compressor are avoided.

CASE 2: DELTA HYBRID-TECHNOLOGY, PERFECTLY SUITABLE FOR APPLICATIONS ON THE CONVEYANCE OF SOLID FUELS

Cement production is a very energy- and emission-intensive process due to the extreme heat required. To produce one tonne of cement, 4.5 billion BTU of energy are required, generating almost one tonne of CO_2. To reach the required temperature to produce clinker, different types of fuel can be used, which all have their advantages and disadvantages – both for the process and for the environment. Thermal energy is the elementary factor of the burning process, as the material has to reach higher temperatures to ensure the proper chemical reaction of the raw material components. At 1,450 °C, belite and calcite are completely moulded into the clinker rock and have the necessary microscopic shape to guarantee that, after pulverisation and mixing of the cement with additives, there is uniform water absorption along the particles, which ultimately determines the quality and strength of concrete. For example, have you ever seen cracks in the road? One possible cause of this is poor cement quality.

> Fuels with a high carbon content, such as coal, which produces a luminous flame, are preferred for kiln firing.

Which fuel is most commonly used in the cement industry? Coal has long been the most popular fuel in the cement industry. A wide range of other fuels such as gas, oil, liquid waste, solid waste and petroleum coke have been successfully used individually or in various combinations as an energy source for firing cement kilns.

Clinker is mainly to its peak temperature by radiant heat transfer, requiring a bright and hot flame (which means high emissivity). Fuels with high carbon content, such as coal, which produces a bright flame, are preferred for kiln firing. Under favourable circumstances, high-quality bituminous coal can produce a flame at 2,050 °C. Natural gas, which reaches a peak temperature of 1,950 °C and is also less luminous, tends to result in lower kiln performance. Clinker must reach a temperature of up to 1,450 °C for the chemical process to calcine the limestone and fuse with other materials to take place. Another important issue is the availability of fuels in different parts of the world. Natural gas is cheaper than coal in most places. However, availability is uncertain as natural gas is the first option for primary supply and cement plants cannot afford to limit the accessibility of the fuel.

Another widely used material is petroleum coke, an oil sub-product with similar heat transfer as coal, but with significantly higher CO_2 emissions per tonne burnt. At the reference site, coal was used as the primary fuel. However, it was also closely examined whether alternative fuels could be an option, mainly because coal prices have been subject to considerable price fluctuations in some cases in recent years, and the availability of coal as a fuel has been limited. In addition, a major expansion project was implemented to increase the plants capacity from 3.2 million t/year to the existing capacity of 5.2 million t/year.

Against this background, the cement plant decided to increase the burner capacity and to convert the plant so that it is suitable for alternative fuels and for petroleum-based fuels such as petroleum coke. The previous burner, which was only suitable for coal and heavy oil (for commissioning only), was replaced by a burner for gas, liquid and solid fuels with different properties up to alternative fuels. The process required a significant investment in engineering and optimisation of the existing equipment. The next graph shows the initial equipment and data in the fuel delivery application at the plant:

Pneumatic conveying of solid fuels

Initial technology: Aerzen Delta Blower GM35 S (3 pieces)
Material handled: Carbon
Conveying method: Air delivery
Conveying capacity: 7,500 kg/h
Conveying speed: 25 m/s
Nominal pipe size: DN200
Volume flow capacity: 37 m^3/min (1306 cfm)

Differential pressure: 600 mbar (8,7 psi)
Maximum pressure: 800 mbar (11,5 psi)
Power requirement: 53 kW (70 PS)
Motor rating: 55 kW (75 PS)
Blower speed: 3,640 l/min
Motor speed: 3,560 l/min
Further data: 1,15 SF, 460 V, 60 Hz

> The process required a significant investment in engineering and optimisation of the existing equipment.

The conveying method in this case is air delivery. Due to the material density and particle size, the initial conveying rate was 7,500 kg of coal/hour, with two AERZEN GM35 S packages in operation and one running in standby mode. The packages produce a volume flow of 37 m^3/min at a pressure difference of 600 mbar. The nominal pipe size is DN200, the power consumption 53 kW.

At the same time, the plant replaced the burner. New operating conditions were required for the fuel delivery system, taking into account both the plant expansion project and the conditions of the alternative fuels. As with most expansion projects in cement plants, the pipelines had to maintain the same length and nominal width, as a complete replacement would have meant a more complex intervention with longer downtime.

Case 2: The challenge

The biggest challenge in this project was not to exceed the limit of 28 m/s for solid fuel conveyance. The pipe diameter was the biggest physical constraint affecting the total mass flow allowed for operation in a DN200 pipeline.

In this case, the total equivalent pipe length (a pneumatic conveying-related value that takes into account both horizontal and vertical pipe segments) was short, no longer than 20 meters. This is advantageous for the calculations, as the pressure drop due to friction and bends is not decisive for the system capacity.

> At the end of the process, the AERZEN team delivered two D98 S Delta Hybrid packages with over 60 % more volume flow capacity and 30 % more pressure capacity.

Advantages of laminar flow when conveying solid fuels

The flow rate is critical for this particular application, as maintaining laminar flow assists the process by providing a stable and sufficient flame from the burner. The air carried with the solid fuel is also called secondary air because it also plays a major role in the combustion and heat transfer processes.

The AERZEN Delta Hybrid rotary lobe compressors were perfect for this application as their internal configuration and higher rotational speed reduces air pulsations and makes the supplied air smooth and laminar. However, exceeding the air supplied into the tube boundary causes the Reynolds number to break, so the air becomes turbulent. This should be avoided as it can lead to expected combustion and a shorter flame.

The result could even be that the burner tip catches fire. At the end of the process, the AERZEN team delivered two D98 S Delta Hybrid packages with a 60 % higher flow rate and a 30 % higher differential pressure. All calculations had to be carried out conscientiously to avoid exceeding the air velocity in the pipe (28 m/s).

Important findings from case 2

- Increase in capacity for coal or alternative fuels by 30 %
- Reduce operating costs by 40 %, including energy savings for technology upgrades and extended maintenance intervals through Hybrid technology
- Increase laminar air flow, which improves flame stability and prevents fire
- At the burner tip by increasing the initial flame distance
- Retention of the piping system
- The system can be expanded in the future by adjusting the volume flow by increasing the speed of the Hybrid and increasing the size of the feed valve for solid fuels

CASE 3: AERZEN HIGH SPEED TURBO TECHNOLOGY COMBINES PERFORMANCE AND RELIABILITY

To successfully operate a rotary kiln in a cement plant, you need a sufficient heat source. It must first heat the kiln to the operating temperature of 1,450 °C and maintain this temperature by compensating for the different heat losses occurring in the kiln system. The heat is obtained by burning fuels, mainly coal, in combination with atmospheric oxygen. To achieve proper combustion, two conditions must be met:

1. sufficient oxygen in the fuel mixture and
2. a constant and stable fuel supply into the system

Depending on the region, there is primary air, jet air or combustion air in the system. All terms refer to the same thing, namely the air supply into the primary burner. The aim is to create a long and wide flame that extends over the entire kiln and ensures the highest heat transfer into the kiln so that proper combustion can be achieved. There are many variables involved in selecting the right equipment for this air supply. However, there is one particularly important variable for the production processes, namely the impulse or mass flow: this variable defines the mass flow of oxygen supplied to the system, thereby ensuring proper combustion. Ambient variables such as the altitude above sea level or the ambient temperature can dramatically influence the impulse and thus the heat transfer into the kiln.

Furthermore, combustion air is the only resource for cement plant operators to control and adjust the kiln temperature when a raw material batch of poor quality enters the kiln or a new fuel type is required. In the past, AERZEN offered high-quality consulting services and provided reliable machines for this application. That is why most of the major cement companies prefer and rely on AERZEN for this specific application.

In the customers cement plant, the situation was critical as the existing blowers for the process were running very close to their operating limit. In view of the burner replacement and additional production capacities, the variable range of the volume flow was very limited. Existing machines could not be increased in their conveying capacity and there was a need to replace them by larger blowers. AERZEN engineers analysed the situation and found that the high-speed turbo technology was a perfect match for the expected operating conditions. The technical data are as follows: the combustion air was initially supplied by two screw compressors with an air mass flow of 5,350 kg/h and a conveying speed of more than 40 m/s with a nominal pipe size of DN200. The volume flow per machine was 74 m^3/min with a differential pressure of 300 mbar and a power consumption of 55 kW.

The challenge in this case was to increase the mass flow through the same pipe system from 5,350 kg/h to 6,800 kg/h. In this case, the application is referred to as process air, as there is no pneumatic conveying of material through the pipes, but only air is conveyed to feed the kiln. But if no material is conveyed through the pipe, how is the differential pressure created in the system?

The answer goes back to the continuity equation, where the reduction of the pipe diameter at the end of the pipe increases the velocity and air turbulence to generate additional impulse and support the combustion process. The most critical limit in this case was the pipe diameter. The increase in mass flow was very important, along with additional turbulence in the system. However, if too much air was passed through this pipe diameter, it could reduce the air performance due to extreme turbulence. In contrast to fuel conveyance, the following applies to combustion air: the more turbulent the air, the better the heat transfer into the kiln and the higher the efficiency of the system.

Given the conditions on site, the AERZEN team suggested installing a high speed turbo blower to provide a constant mass flow through a high speed impeller for maximum control, reliability and the additional mass flow as necessary due to the pipe diameter limitation. In addition to this advantage, Aerzen Turbo offers an integrated inverter that helps to control the system and the air flow in case of an alternative fuel or a change of the raw material mixture. This application helps the operator to control the process in the same way as for oxygen supply and adjustment of a burner.

> In the customers cement plant, the situation was critical ...

Important findings from case 3

- The use of turbo technology increased the air velocity, which created additional turbulence in the mass flow, making the flame larger and more robust
- The turbo package was supplied with an integrated frequency inverter to allow the process to be controlled as needed
- Reduced space requirements compared to other technologies
- Significant reduction in maintenance costs
- Power consumption is reduced by 30 % compared to alternative technologies
- Additional control of the process to handle different raw material batches and new alternative fuels
- Remote monitoring of the most critical process through HMI data transmission
- High reliability for the most critical application in the plant

We combine the best of more than 150 years of experience.

„At AERZEN, our application knowledge has supported numerous projects around the world. We combine the best of more than 150 years of experience in manufacturing highly reliable blowers, compressors and turbos with the demands of plant operations to ensure that any material conveyed through a pneumatic conveying system is delivered reliably and efficiently from source to destination.“

David Salazar – AERZEN-Regionalleiter für pneumatische Förderanwendungen

FOR MORE INFORMATION ON AERZEN SOLUTIONS FOR THE CEMENT INDUSTRY, PLEASE VISIT:
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AERZEN. Verdichtung als Erfolgsprinzip.

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 lobecompressor package. Innovations "made by AERZEN" keepdriving 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, stability of value and efficiency. Go ahead – challenge us!

FIND YOUR LOCAL CONTACT

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