Pumps + Systems
Compressors, Compressed Air and Vacuum Technology

VDMA

Pumps and Compressors for the World Market 2025

with Compressed Air and Vacuum Technology

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This is the VDMA specialised magazine for engineers and the technical management. Please order print or digital simply by sending an e-mail to heidrun.bilek@vdma.org or register online via http://subscription.vdma-verlag.com The magazine is published once a year in April and it's free of charge.

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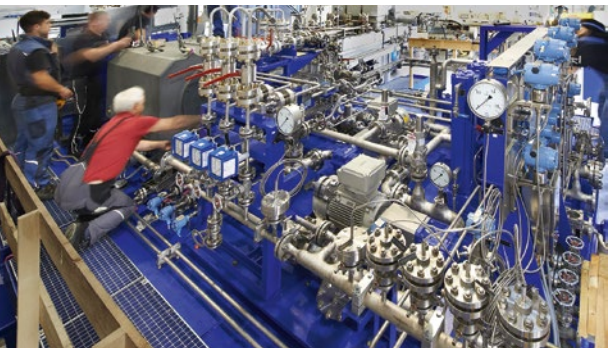

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Part II: Compressors, Compressed Air & Vacuum Technology

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Pump and compressor manufacturers are optimistic

Dear readers,

Nicolaus Krämer

Alexander Peters

Unfortunately, the global crises continue to keep us on tenterhooks this year. The human suffering associated with these crises leaves us feeling saddened. We take a critical look at the political changes worldwide in 2025. However, we were pleased to note that, according to the environmental organisation Germanwatch, no form of energy has ever grown as fast as renewable energy. We share their view that global efforts to protect the climate should be further intensified. This is both a source of hope and an incentive for us. After all, our industries have been committed to reducing CO_2 for decades and will continue to do so, as you will read in this year's issue of our magazine "Pumps and Compressors for the World Market 2025".

After a very good start to the year in some areas, 2024 presented a number of challenges for the members of our two sectors. The global economy did not perform well last year. Many companies recorded a decline in incoming orders, as you can read in the interview with Christoph Singrün. In it, he also takes a look at the different developments in the sub-sectors. Contrary to the general trend last year, manufacturers of process compressors, for example, are experiencing a certain boom. They are recording very good incoming orders, as many hydrogen projects have been added. Christoph Singrün also emphasises that the quarterly VDMA economic survey is an important indicator of business development. The survey in the fourth quarter indicated that incoming orders in both sectors are bottoming out to a certain extent, but that the order situation is likely to improve in the first half of 2025.

Christoph Singrün also discusses the F-Gas Regulation, which will have far-reaching consequences for the compressed air technology sector. This is because the EU has brought forward the target date of 2023 significantly, which places corresponding demands on manufacturers. The regulation aims to reduce the global warming potential of the refrigerants used. Naturally, we support this. But the use of alternatives is not obvious, as you will learn in the interview. Christoph Singrün takes an equally critical look at the current status of PFAS regulation. With regard to demographic change, he recommends taking a two-pronged approach: On the one hand, the aim should be to keep older employees in work for longer. On the other hand, we should get younger people interested in technology at an early age and show them that our professions are attractive.

There has been a positive development in the budget for the International Trade Fair Programme (AMP), which has returned to its pre-pandemic level. The VDMA is also a major applicant in the AMP, which benefits SMEs in particular. This allows companies to present themselves in attractive markets under the umbrella of the German Pavilions, benefit from favourable conditions and, last but not least, help to create and secure jobs in Germany.

For the first time this year, our readers can look forward to a second interview with Dr Kristian Müller-Niehuus, who deals with the introduction of the Digital Product Passport. In it, he describes what manufacturers and users can expect and what they should ideally already be dealing with today. After all, the effort that companies will have to put in should not be underestimated. However, Dr Kristian Müller-Niehuus firmly believes that the Digital Product Passport will not only create transparency, but also added value.

In the current issue of the magazine, we once again present a variety of innovative solutions developed by our members. For example, you can find out how the heat transition can be driven by concentrated solar thermal energy, how centrifugal blowers increase efficiency and how modern leak detection systems help to ensure the tightness of cooling and refrigeration circuits. These are just a few of the many solutions that are available for the diverse applications of pumps and compressors. As every year, the authors of the articles look forward to answering any questions you may have or are interested in specific topics. The experts are looking forward to exchanging ideas with you. We wish you a fascinating and informative read.

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“Light at the end of the tunnel”

The past year brought many challenges. Both sectors are going through a certain trough. But many are positive about the current year.

Christoph Singrün

Interview with Christoph Singrün, the Managing Director of the VDMA associations Pumps + Systems and Compressors, Compressed Air and Vacuum Technology.

The past year was challenging. How did it develop?

I would go back another year. Many members reported record sales in 2023. This means they got off to a good start last year across both sectors, i.e. pumps and systems as well as compressors, compressed air and vacuum technology. As some companies still had a cushion of orders, they were able to maintain their turnover for a long time. However, the global economy did not develop so well last year. As a result, companies were no longer able to maintain the peak level of incoming orders. Overall, incoming orders fell by around 10 per cent. Sales in the Pumps + Systems segment did not quite reach the record year of 2023. Compressors, compressed air and vacuum technology must be viewed in a differentiated manner, as manufacturers of vacuum technology experienced significant declines. During the coronavirus pandemic, they recorded a significant increase, while the semiconductor industry invested heavily. These investments are now missing. The situation is much more positive for process compressors, meaning that we expect the industry as a whole to just be able to maintain its sales level in 2024.

Keyword VDMA quarterly economic survey: How do companies assess the situation?

Manufacturers of process compressors are currently experiencing a certain boom. They are experiencing record order intake as many hydrogen projects have been added. Around a third of compressor manufacturers rate their business situation as good or even very good, as do almost 20 per cent of pump manufacturers. So there is light at the end of the tunnel. In the survey in the third quarter of 2024, we also asked about expectations for the next six months. This is an important indicator. A full 80 per cent of pump manufacturers assume that the situation will not change. Similarly, 44 per cent of compressor, compressed air and vacuum manufacturers expect the situation to remain unchanged in this period. There are some indications that we are passing through a certain trough in terms of incoming orders in both sectors. Based on the autumn survey, there are therefore initial glimmers of hope that the order situation will improve again in the first half of 2025.

PFAS regulation is jeopardising the existence of many companies. What is the current situation?

The current situation is unchanged: If the regulations were to come in as submitted, it would be a disaster. The six-month consultation ended in September 2023. At that time, around 6,000 comments were received from companies across Europe. These are now being processed and answered in European risk assessment committees. It simply takes time to provide a qualified response. Originally, eight to ten weeks were planned for this process. This shows that those responsible in the EU have completely underestimated the situation. We are now not expecting the final scientific assessment until the end of 2025, which means we are at least a year behind schedule.

Just one year?

Not just one. Because then the two-year decision-making process starts on the basis of the assessment submitted. The positive thing is that it is a very democratic process. But of course this makes the process very time-consuming. How-

ever, the longer the process drags on, the more manufacturers of these materials will withdraw from the business due to the potential risk. This is causing great uncertainty in the market. We are currently seeing a sense of attentiveness. This means that investors are taking a wait-and-see approach as the framework conditions for the industry are not clear. That is why we urgently need a clear political framework.

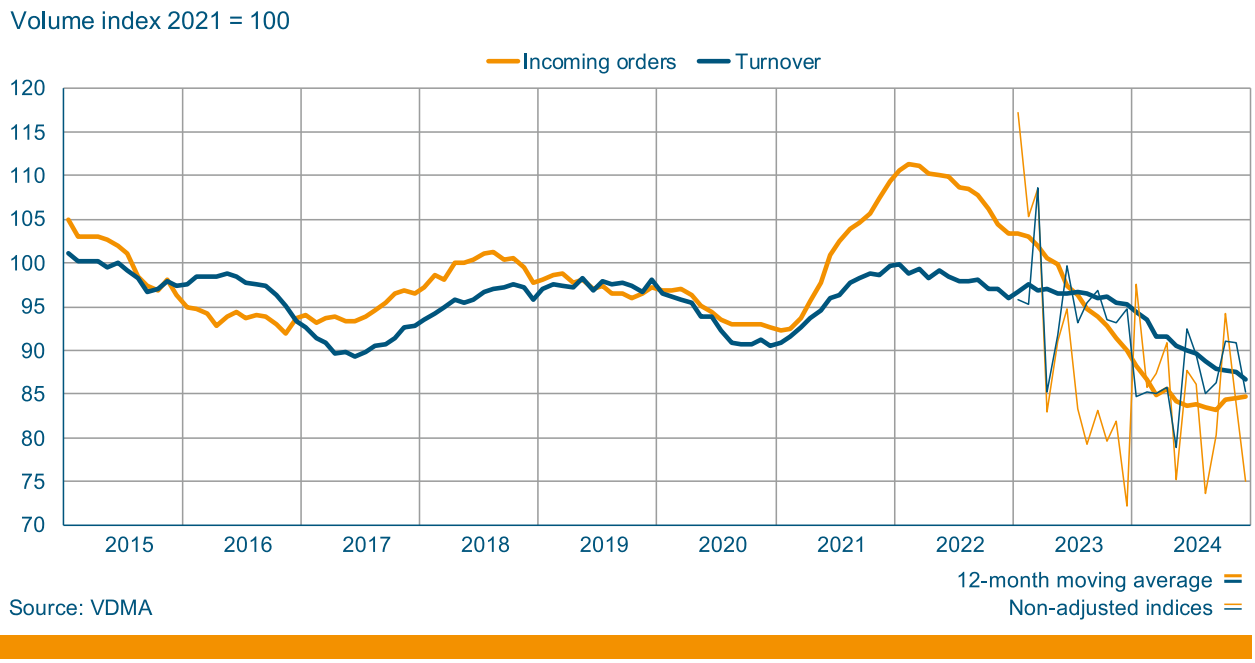
The amended F-Gas Regulation also places demands on manufacturers and operators. What's in store for manufacturers?

The regulation came into force on 11 March 2024 and has far-reaching consequences for the compressed air technology sector in particular. Above all, the regulation affects refrigerants. Their global warming potential must be reduced. We also support this. However, the EU has brought forward the target date of 2023 in a kind of cloak-and-dagger operation. This means that implementation is to take place much faster than originally planned. The majority of these gases should no longer be on the market by 2030. In principle, the solutions would be flammable and toxic refrigerants, as they have a significantly low greenhouse gas potential. The best example is propane. It is considered a natural refrigerant for heat pumps. However, propane has the major disadvantage that it is highly flammable. For compressed air dryers operated indoors, this is dangerous in the event of a leak, as a highly flammable mixture is created. This jeopardises employee safety and much more. Together with the Pneurop sector committee, we submitted our position paper, which was recognised by the EU Commission. This gives us a certain transitional period in which compressed air dryers can still be operated with F-gases until the beginning of 2027. However, manufacturers must of course look for alternatives.

Are there any other regulatory issues that concern members?

We are still experiencing a "regulatory tsunami". Many members are asking themselves what this kind of bureaucracy means for them and for their customers. On the other hand, the new EU Machinery Directive is certainly to be welcomed, as it is about safety. It will come into force on 20 January 2027. It replaces the previous Machinery Directive. The challenge here is to revise all existing, harmonised safety standards. As this cannot be implemented overnight, so-called GAP analy-

Incoming orders and turnover in Germany – Pumps



Source: VDMA

ses have been carried out. These are intended to show what is missing in order to fulfil the new directive. We assume that it will not be possible to revise the standards before the directive comes into force, but thanks to the GAP analyses, a transitional arrangement has been created for all parties involved.

Most German mechanical engineering companies concentrate on research and development. What about joint industrial research?

The VDMA relies heavily on joint industrial research. It creates outstanding innovation networks between industry and science. We are calling for this instrument to be expanded further and for a significant increase in government funding for this purpose. We are also focussing on tax incentives for research, which were introduced years ago and have been an economic policy demand of the VDMA for many years. Companies that are highly innovative receive subsidies and decide for themselves which new markets they see for their products.

What do you expect from politicians?

Politicians should create clear economic framework conditions for investment. They should call for more investment and less consumption. Of course, that doesn't go down well. That's why it lacks the courage to do so. We should instil in people's minds that we need to invest more for economic growth. When we talk about climate change, we need to reorganise our industry. We need to invest in new technologies and processes. This will require huge investments, which will also affect the private sector. In the VDMA's economic policy positions, we call for a strong but lean state, investment promotion and investments in education. Reducing bureaucracy is a top priority for all our members in this context. The duration of approval procedures should also be urgently shortened and the modernisation of infrastructure driven forward.

Where do your members stand in terms of digitalisation?

Some members already have fully digitalised production facilities. There are certainly still challenges. Keyword interoperability at product and company level. There is still room for improvement. But we have already achieved a lot here together with our members when it comes to the OPC UA Companion Specification or the administration shell. I see us in a leading position in terms of the foundations for this.

Has the use of artificial intelligence changed in the last year?

Predictive maintenance or condition monitoring is not entirely new in this context. The manufacturer has access to the operating data of the customer's pumps and compressors. Manufacturers and operators learn from this data using AI-based tools, for example, when the pump needs to be serviced. The interaction between manufacturer and customer is important here. Manufacturers must be able to view the customer data and evaluate it together with the customer. For this purpose, we offer our members an orientation guide, Smart Service Compressed Air Vacuum 4.0 - Added Value from Machine Data. In it, we address the key questions on the topic, including issues of trust in relation to operating data. We want to help reduce existing concerns in order to utilise AI tools and thus increase added value.

We have the ongoing issue of demographic change. What can VDMA members do?

In terms of the mechanical and plant engineering industry as a whole, we assume that 180,000 employees will retire over the next ten years. This means that securing skilled labour is a huge challenge. We have to take a two-pronged approach. On the one hand, this means that we have to keep older employees in work for longer. Of course, a lot needs to be done politically when it comes to the standard retirement age. Social attitudes towards this must also change. We should create an awareness that the experience and skills of older employees are indispensable to us. Anyone who wants to continue working after the statutory retirement age should be allowed to do so. There is great potential here. We are very active in this area together with our members and the VDMA's Education and Modern Working department. Together with our members, we are particularly active in the area

of young talent, for example with the VDMA Talent Machine. We need to get younger people interested in technology at an early age and show them that our tprofessions are attractive. This also applies to the traditional STEM subjects in schools.

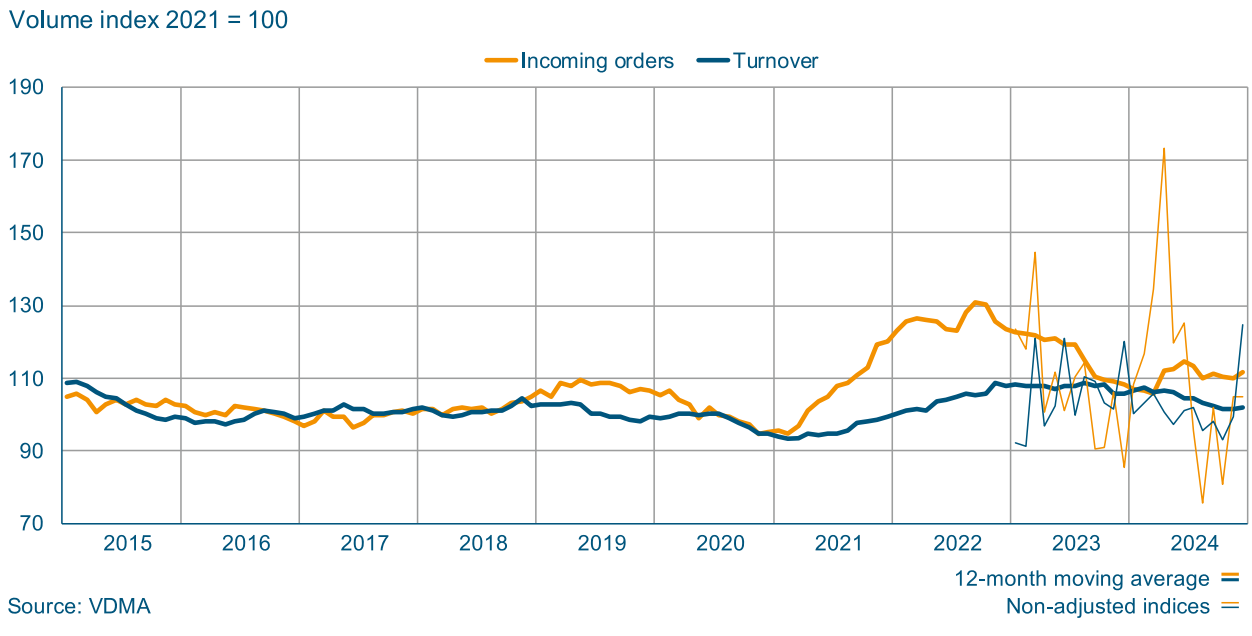
China is catching up fast. What options do German manufacturers have?

China has been the largest exporter of machinery and equipment since 2020. Last year, we produced the "China Going Global" study for our members. In it, we explain options for action, such as political framework conditions. This also includes strengthening Germany as a business location in order to reduce the price-related competitive disadvantages of our members. In addition, export licences must be made easier. Exports to China are severely hampered by the lack of export licences in Germany. Last year, orders worth millions were not approved in some cases. Economic diplomacy is another issue. Here we organise delegation trips so that our members can better compete on the Chinese market. There is also a difficult but important issue that we have to address. We need to start talking about anti-subsidy or anti-dumping measures in the event of truly unfair Chinese competition. This applies if the applicable WTO rules are demonstrably violated. Further free trade agreements should also be promoted by the EU. If these are lacking, this will inevitably lead to a competitive disadvantage for manufacturers.

Some VDMA members are sceptical about 2025. What is your assessment for pump and compressor manufacturers?

The current year is characterised by great uncertainty, also geopolitically. However, based on developments over the last two years, we expect incoming orders to recover. We currently assume that both sectors will be able to reach the turnover level of 2024 again this year. What is important here is whether incoming orders will pick up in the first half of the year or not until the second half. The latter will not be invoiced until 2026. There is still some uncertainty here. Despite all the difficult circumstances in recent years, we are cautiously optimistic. We are focussing on customer proximity, innovation and good product quality. In this respect, our members can hold their own very well on the markets.

Incoming orders and turnover in Germany Compressors, Compressed Air and Vacuum Technology



Source: VDMA

73 companies from the German Pavilion welcomed their customers at ADIPEC 2024 in Abu Dhabi. Source: VDMA

VDMA is an important applicant in the foreign trade fair programme

Ulrike Mätje

The foreign trade fair programme of the Federal Ministry for Economic Affairs and Climate Action (BMWK) includes around 250 trade fairs this year. That is around 30 more than last year. The most important applicant is the VDMA, which has proposed a total of 70 trade fairs. This offers German companies the opportunity to present themselves in attractive markets under the umbrella of “Made in Germany”.

The funds for the International Trade Fair Programme (AMP) in the BMWK budget amount to around 44 million euros. This puts the budget back at its pre-pandemic level. However, in view of global cost increases, the Association of the German Trade Fair Industry (AUMA) is calling for the budget to be increased by five million euros to 49 million euros. This is the only way to maintain the quality of German pavilions.

The AMP has proven its worth for more than 75 years. The programme offers German companies the opportunity to participate in international trade fairs under the umbrella of the so-called German Pavilions. The foreign trade fair programme supports companies in opening up international markets, as they benefit from favourable conditions. On the one hand, this can help to create and secure jobs in Germany.

On the other hand, the AMP can help to maintain the international competitiveness of manufacturing companies.

Foreign trade fairs boost exports

Even more important is the support provided by a German trade fair organiser in the run-up to and during the trade fair. This is because the trade fair companies usually ensure favourable positioning in the hall and meet the demand for "Made in Germany" stand construction. In particular, this attracts the attention of visitors to German exhibitors already known in the market.

This helps exhibiting companies to concentrate on the essentials: on their exhibits, the involvement of stand personnel, the presentation of their portfolio and their services. They can focus on acquiring new customers, sales and investment partners. Small and medium-sized companies in particular look forward to participating in the German Pavilions, as experience has shown that this can boost their export quota. In addition, the federal government contributes to the direct trade fair costs via the AMP. The remaining amount is borne by the exhibiting company. Studies show that participation in trade fairs abroad boosts German exports enormously. According to the Association of the German Trade Fair Industry (AUMA), the investment of one tax euro generates around 216 euros in added value.

Asia's attractiveness as a target region remains unbroken

As in previous years, the most important target regions of this year's programme are the Asian markets: the AMP supports more than 90 joint stands of German companies there. Another target region of the programme is North America with almost 40 participation opportunities. The Near and Middle East is also represented again with 34 participations, followed by Africa with 26. 35 German Pavilions are planned at trade fairs in Europe, eleven of which are outside the European Union. More than 20 participations are planned in Latin America, while six joint stands are planned for Australia/Oceania.

At country level, the USA is one of the three most important countries in the foreign trade fair programme with 33 participations, followed by China and the United Arab Emirates with 26 each. India is in third place with 18 participations, while Thailand, Brazil, South Africa and Turkey share fourth place with eight participations. In the current year, Saudi Arabia is increasingly becoming a target country for German industry: seven participations are planned in Riyadh alone. Five of these trade fairs have been included in the AMP for the first time.

Online registration has proven its worth

Digital registration and application for the AMP has been standard practice since last year. This offers participating companies several advantages: After a one-off accreditation and subsequent activation, it is possible to register for individual trade fair participations. Above all, this saves time: Once the company data has been entered, it is already available for further registrations. Exhibitors also receive recommendations for other trade fair participations in the target region or for their sector. The programme also offers companies the opportunity to search specifically for trade fairs and to register for future projects. Anyone who has already expressed an interest will be automatically informed about the start of the registration phase. This is an advantage that should not be underestimated, especially for the highly popular German Pavilions.

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“Digital product passport creates transparency”

There is much criticism of the effort required to introduce the digital product passport. But the advantages outweigh the disadvantages.

Dr Kristian Müller-Niehuus

Interview with Dr Kristian Müller-Niehuus, Technology and Regulation Officer at the VDMA Pumps + Systems Association.

The digital product passport is a central component of the Green Deal. What is the current status?

We assume that the digital product passport (DPP) will be activated for a large number of products in 2026. These will initially include textiles, iron and batteries, for example. Others will then be added, such as motors followed by pumps and compressors. As the DPP is organised by lots, we cannot say with certainty when the respective DPP will become binding for our members. In addition, experience during the introduction of the DPP will be incorporated into the schedule. I estimate that it will be the pumps’ turn between 2030 and 2033.

What does the introduction mean for manufacturers?

Manufacturers must implement a digital system in which data is stored, for example the energy efficiency, the proportion of recycled material in the product or how many operating hours a pump has run. The latter is primarily of interest to the secondary market.

What about the users?

There are two things for operators, because every user is also a supplier. On the one hand, this means that they must transfer all the data from their suppliers to the DPP, and on the other hand, they have to add their own data to their DPP. The updated DPP is then passed on to the customer, who can use the data and integrate their own data.

Must or can?

Both. Because there is voluntary data such as certificates or transport routes, and mandatory data such as materials, components and disposal information. The latter is passed on to the recycler when the pump is taken out of service. Among other things, the recycler can then evaluate the raw material data, disassemble the pump and recycle its individual parts accordingly.

How do you estimate the costs for the development of a system that can map the digital product passport?

I assume that the effort for the companies will undoubtedly be very considerable. They will have to structure, classify and provide the associated data in order to transfer it to the DPP in an organized manner. You can think of it like a drawer system. For example, companies must check where they store the waste code in the DPP. If necessary, companies must first ensure that such DPP data points are generated. This might be a huge amount of work for companies. Once companies have structured the relevant data, it should be relatively easy to complete the digital template for the digital product passport. In addition, many of these key figures are also required by other regulations, for example, for reporting obligations or even for credit applications in the future. This means that companies can use the entire set key of figures again and again. However, there are so many regulations coming at companies at the moment that they often don’t know where to start.

Data, such as the recycled content of the product, must be stored in the digital product passport. Source: Shutterstock

And the supplier's data is also included

Exactly. The data set is constantly growing. You can imagine it like a pyramid. In the pump unit, consisting of pump, motor and variable frequency drive, each component has its own digital product passport. Which could be further broken down into components such as the housing, impeller or bearing, right down to the screws. In the case of the motor, it will play a role where the magnets come from or how much copper is used. All of this will be stored. It remains to be seen what information each user will be able to access. In the case of textiles, for example, QR codes are already used to provide information about where the cotton comes from or how much CO_2 the processed cotton has generated. This information is publicly accessible. However, there will also be a protected area where data such as operating or repair instructions will also be stored. In the case of components that should only be handled by trained specialists only these people will have access. On the other hand, the recycler has access to raw material data that the mechanics cannot see since they do not need this information. There is still a great need for clarification about the security functions of the DPP and it must be clarified who can ultimately access which data.

Keyword pyramid - do the companies have the data required in the digital product passport?

The data is available, but not in the structure and format required. Every manufacturer knows the components of its product down to the last detail. However, the data may not be available in the appropriate data format to be shared in a DPP-compliant manner.

What do you recommend to companies?

Companies should definitely familiarize themselves with the Ecodesign for Sustainable Products Regulation (ESPR), as the DPP will appear under this as a delegated act. This is essential for

Source: Shutterstock

Pumps are used in textile laundries which carbon footprint will be listed in the DPP in future.

the circular economy. If manufacturers believe that they won’t have to worry about it for another ten years because they have nothing to do, for example, with steel, this is simply a misconception. Because there is also an indirect impact when iron and steel are purchased for the pump. The base plate, the impeller and the flange are made of steel. Companies must be able to record the data and at least pass it on so there is not a hole in the pyramid. If manufacturers are unable to do this, they will be at a competitive disadvantage because their competitor already dealt with it at an early stage. They may have already started to structure the data.

Do you have an example of this?

For example, pumps are used in textile laundry. It could be that a textile manufacturer asks what the CO_2 footprint of the pump is. This is because the textile manufacturer has to take this into account, and it flows into their end product. It could therefore be that manufacturers are asked by their customers to provide information on the DPP, even though they, as pump manufacturers, are not yet affected by the DPP. If the company does not provide this information, it is likely that it will not receive the order.

Can data such as the CO_2 footprint be compared with each other?

There are still no clearly agreed calculations that allow comparability, for example in the calculation of CO_2. As a result, manufacturers’ answers to such questions can still vary greatly.

However, the digital product passport will then provide a standardized definition.

We hope so. But there is still a risk of non-comparability. For example, it currently depends on the location of production. In the EU, nuclear energy is currently categorized as environmentally friendly. However, if the pump is produced in Germany, a significant proportion of fossil fuels are used and the CO_2 footprint of the German energy mix is included in the DPP. This means that manufacturers must enquire about the energy mix of the country of production on the day of production and derive the current carbon footprint for the product from this. Country by country - this creates distortions. This also applies to the dark season, when many countries use more fossil fuels for production. It is currently still completely unclear how this will be dealt with in future. We are there-

fore calling for the current European energy mix to be used. This will equalize locational disadvantages.

Apart from the questions that are still unanswered, what are the advantages of the digital product passport?

One major advantage, for example, will be that manufacturers will be able to prove in black and white how much recycled material a product contains, how much waste the production process has generated or where the purchased steel comes from. Whether it was produced conventionally or green. Companies can use this for marketing and show that their products comply with the Green Deal. Companies can also optimize processes because they have key figures on the raw material. For example, how old a raw material is, when and where it was produced. Manufacturers can use this information to adapt process technology accordingly, as an older material may need different manufacturing conditions than a new one. Knowledge of all these parameters offers great advantages for optimizating processes within the company.

Are there any other advantages?

The introduction of the DPP will certainly also result in new business models and new jobs. The profession of data scientist already exists today. However, the DPP is a new use case in which a data scientist can, for example, reveal correlations that are not obvious. End users can view the data relating to their product. Take the e-car, for example: the battery passport will show how many charging cycles the battery has already had or what quality condition it is in - crucial when buying a used e-car. And another particularly important point: if the work is done properly, greenwashing is no longer possible.

Is there anything that speaks against the digital product passport?

As we now know that other large third countries such as America and China are also working on a type of DPP, it is fair to say that Europe will be the first to tackle it, but it will also play a pioneering role. Critics are primarily focusing on data security, as companies have to store sensitive data. Many fear that company secrets will become accessible: Raw materials, their composition, drawings for spare parts, instructions - all sensitive information. Can it always be ensured that only authorized persons have access? Secondly, the DPP is a decentralized system in which the companies store the data internally, but they also have to create a backup. This means that they have to commission an external, independent party to host the data. However, all of this also generates additional costs over the entire life cycle of the product or at least for ten years. Companies will incur initial costs, especially during the introduction phase. This is because data preparation, additional IT positions, upgrading the IT structure in line with the DPP and ultimately the backup service will be necessary.

This generates huge amounts of data. Does the expense associated with data security conflict with sustainability?

There is a study that aims to show how much energy the data storage of this pyramid will consume. It is also looking into the question of whether this energy consumption is in proportion to the protective function that the circular economy is supposed to provide. I am very excited about the outcome. I am sure that the positive aspects will outweigh the negative and that the DPP will be a successful model. It could reduce the EU's dependence on raw materials: Batteries contain rare earth materials or neodymium in magnets, which we hardly ever get in Europe. Circulating the raw materials in Europe and reusing them reduces our dependence on imports.

Give us an outlook.

I would argue that we should start with just a few key figures and not immediately start with hundreds of data records, 90 percent of which later turn out to be irrelevant. It will be jarring at the beginning. But as soon as the circular life of a pump offers added value, acceptance and implementation will pick up speed. The digital product passport will create transparency and strengthen trust in products. I am convinced that the digital product passport will create added value.

The sulphur acid pump can be easily retrofitted.

Source: Rheinhütte Pumpen

Conveying hot sulphuric acid efficiently

Stephan Näckel, Tobias Mai

Energy efficiency and sustainability are the buzzwords when it comes to heat recovery systems. By using thermal energy efficiently, operators of sulphuric acid plants reduce their CO_2 footprint. Users also benefit economically from this use of energy. In this process, corrosion-resistant materials and durable shaft seals are two key design features of the pumps that convey the hot sulphuric acid.

Sulphuric acid is one of the most important basic chemicals in numerous global industries. More than 200 million tons are produced worldwide every year. However, production causes enormous amounts of CO_2, which pollutes the environment, and valuable resources, such as the waste heat generated in the process, are wasted. Heat recovery systems (HRS), which utilize the highly exothermic processes in the production of sulphuric acid, provide a remedy. These systems can be integrated into sulphuric acid plants and adapted to the respective requirements of the plant. The aim is to recover waste heat in the form of high and medium pressure steam. Users can use this process steam for other processes or to generate electricity.

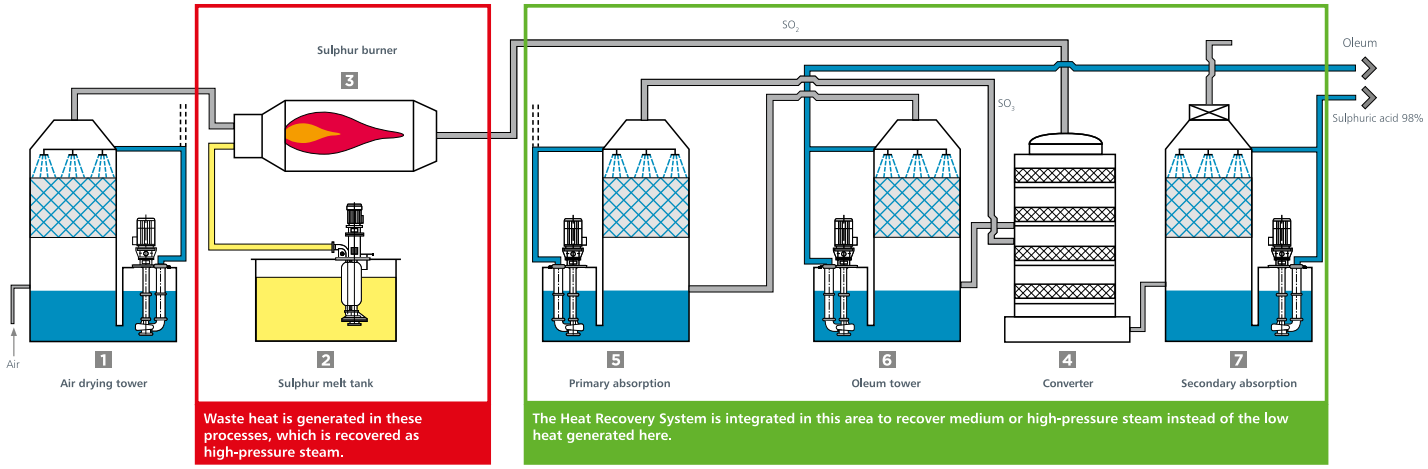
More than half of all global energy is generated from heat. However, electricity generation from heat is usually based on the combustion of hydrocarbons, which causes high CO_2 emissions. The combustion of sulphur to sulphur dioxide (SO_2) and the conversion of sulphur dioxide to sulphur trioxide (SO_3) releases large amounts of heat, which can be recovered as high-pressure steam. The recovery of this waste heat represents a carbon-free and therefore environmentally friendly way of generating energy.

What are heat recovery systems?

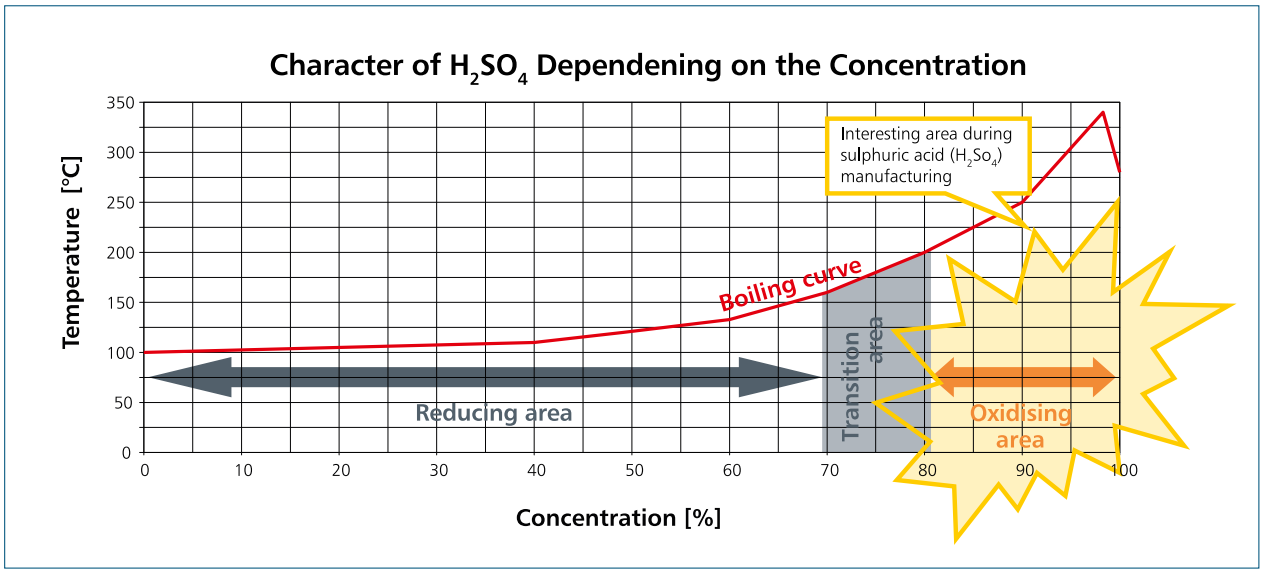
In a typical sulphuric acid production process cycle, around 60 percent of the total energy can be used as described above. Approximately 3 percent is dissipated with the exhaust gas via the stack, almost 0.5 percent is lost as sensible heat in the product acid and 35 to 40 percent is available as weak heat in the acid cooler system. The HRS comes into play with the weak heat in order to utilize it - which would otherwise end up in the atmosphere or in the cooling water system. This means that users can utilize almost all of the waste heat by using a heat recovery system.

This requires minor changes to the acid cooling process (absorption and dry tower cooler). This part of the process is modified so that the processes can run at a significantly higher temperature, but still achieve the required SO_3 absorption levels and at the same time limit the corrosion of the acid system. A large proportion of the SO_3 contained in the process gas is absorbed, so that the user has to monitor and control the sulphuric acid concentration, which is between 98.5 percent and 99.7 percent. Due to the absorption of SO_3 and its reaction with the water introduced, the acid temperature rises to a higher level. Heat is removed from the

Source: Rheinhütte Pumpen



HRS applications recover the enormous amount of heat generated in sulphuric acid plants.



Source: Rheinhütte Pumpen

HRS processes demand the highest standards of corrosion resistance from the material.

acid and water is added in the next step to keep the acid concentration within the limits required for the process. The energy contained in the product acid is then recovered by heating water, which generates additional steam, reducing the total amount of steam required for consumption in the acid plant. The hot acid flows by gravity into a pump tank, from where it is pumped back into the HRS tower through the acid cooler. The remaining SO_3 is then removed in the downstream intermediate absorption tower.

Easy to retrofit or customize

The topics of sustainability and reducing carbon emissions are more topical than ever today and are a focus for users. The newly developed system can be easily retrofitted in existing sulphuric acid plants. It is designed in such a way that it can be switched off while the intermediate absorption tower remains in continuous operation. Users can therefore operate the system with or without HRS at any time.

Source: Rheinhütte Pumpen

In 2013, the company installed the NPSH measurement setup of the prototype on the test bench.

Depending on the system configuration, additional production of low to medium pressure steam is possible. A large proportion of the low-pressure heat generated in the absorption tower of the acid plant is converted into valuable steam, while cooling water consumption is reduced to the same extent. When used in a newly planned plant, the HRS system to be integrated can be individually modified to generate the maximum possible amount of steam.

Source: Rheinhütte Pumpen

The four-meter-high pump can only be placed with a crane.

Hot sulphuric acid – major challenge for conveying

The challenge for pump manufacturers such as Rheinhütte Pumpen from Wiesbaden in this application lies in the high aggressiveness and extreme temperature of the acid as well as in the size and efficiency (> 80 to 85 percent) of the pumps. Sulphuric acid is one of the strongest acids. It is highly caustic and corrosive, so

Options for using the recovered waste heat

- Power generation
- Preheating of boiler feed water
- Heating medium in connected processes or neighboring plants
- District heating supply for surrounding towns and communities
- Production of fresh water through desalination of seawater or brackish water (for plants near the coast)

Source: Rheinhütte Pumpen

only a few pump materials are suitable. The corrosion resistance of sulphuric acid mainly depends on the concentration and temperature. In HRS processes, approximately 99.5 percent sulphuric acid is pumped at around 220 °C, which places very high demands on the corrosion resistance of the material.

The corrosion resistance of a material can be calculated using a mathematical formula. A so-called corrosion index (HRS - Corrosion Index) is determined based on the chemical composition of the alloy. Only a few manufacturers offer pumps with this or a higher corrosion index. In addition to the specific choice of materials, other design features are also decisive. A central factor is the sealing of the pump. For vertical HRS pumps, single-acting, gas-lubricated mechanical seals in cartridge design with a throttle on the tank side are the optimum choice. The throttle reduces the sealing gas consumption by creating a gas cushion. This protects the seal and minimizes the escape of the container atmosphere. The gas also keeps unwanted atmospheric oxygen or humidity away from the gas seal. In vertical pumps that operate at lower temperatures, a stuffing box packing can be used as an alternative.

Source: Rheinhütte Pumpen

The vertical pump is installed in the tank of the sulphuric acid plant.

Due to the highly corrosive properties of the medium, the manufacturer does not use screw connections wherever possible. Screw connections that are located in the medium are fitted with cap nuts and additional O-rings. The flanges are cast onto the pipes instead of bolted to prevent crevice corrosion. The pumps also have a dual volute, which greatly reduces the radial loads, resulting in less stress on the shaft and rolling and sleeve bearings. In order to minimize partial load recirculation (reduction of NPSHr), the manufacturer has fitted the suction covers with swirl breakers.

From prototype to market launch

In 2013, Rheinhütte Pumpen started with HRS prototypes for a sulphuric acid plant of a European fertilizer manufacturer. Existing pumps

from another manufacturer were to be replaced. In both cases, vertical pumps were required that could pump 99.5 percent sulphuric acid at 224 °C. The Wiesbaden-based company chose a pump type that had already proven itself in sulphuric acid plants for decades. The only difference to previous projects was the enormous temperature of the sulphuric acid. However, the special material previously used in sulphuric acid proved to be resistant even at these temperatures. This is a corrosion- and erosion-resistant, high-alloy ferritic cast steel. This material can also be used for the shaft, or alternatively a duplex. This is a semi-austenite, molybdenum- and copper-alloyed material with high resistance to pitting and stress corrosion cracking. This allowed the manufacturer to use the existing material for the new application. However, the hydraulics and design had to be optimized to prevent crevice corrosion, for example.

By using a heat recovery system, users can utilize almost all of the waste heat.

Rheinhütte Pumpen supplied four of these pumps over a period of two years. The first three pumps were equipped with a double-acting mechanical seal. A single-acting, gas-lubricated mechanical seal was installed in the fourth pump. This design proved to be an equally suitable but more cost-effective solution. Following the successful use of the HRS prototypes, the manufacturer has launched a project to implement further sizes for HRS applications in order to be able to cover flow rates of up to 4,000 m³/h and delivery heads of up to 30 m. The company has also made the leap to Asia. The company has also already made the leap to Asia: since 2021, an HRS pump from Wiesbaden has been smoothly conveying 99 to 99.5 percent sulphuric acid at 220 °C in a sulphuric acid plant in China.

Solution approach for a CO_2-neutral future

HRS applications enable operators of sulphuric acid plants to achieve a positive energy balance. A sulphuric acid plant with a capacity of 3,000 MTPD (Metric Tons Per Day) can avoid up to

300,000 tons of carbon dioxide emissions per year by adding a heat recovery system. Looking at the annual production volume of sulphuric acid, it quickly becomes clear that this system can play a central role in decarbonizing this segment of the economy. Plant operators also benefit economically, as a large proportion of the energy required for the plant can be generated in-house and the investment is usually amortized within a maximum of three years. The use of an HRS application is also attractive because no adjustments to the pipes or the tank in the system are required. This means that customers can continue to use their existing electrical supply.

A sulphuric acid plant with a capacity of 3,000 MTPD can avoid up to 300,000 tons of CO_2 emissions per year by adding a heat recovery system.

Previously, there was only one pump supplier for HRS applications, which therefore had a certain monopoly position. Thanks to Rheinhütte Pumpen's offer, operators now have the option of choosing between two suppliers - both for existing and new systems. This means that operators can benefit in terms of flexibility, prices and service in the future. There are only a few manufacturers in the world who can also develop pumps for this challenging application. It remains to be seen whether more pump suppliers will be added in the future.

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Source: Rheinhütte Pumpen

By using an HRS, users can utilize almost all of the waste heat.

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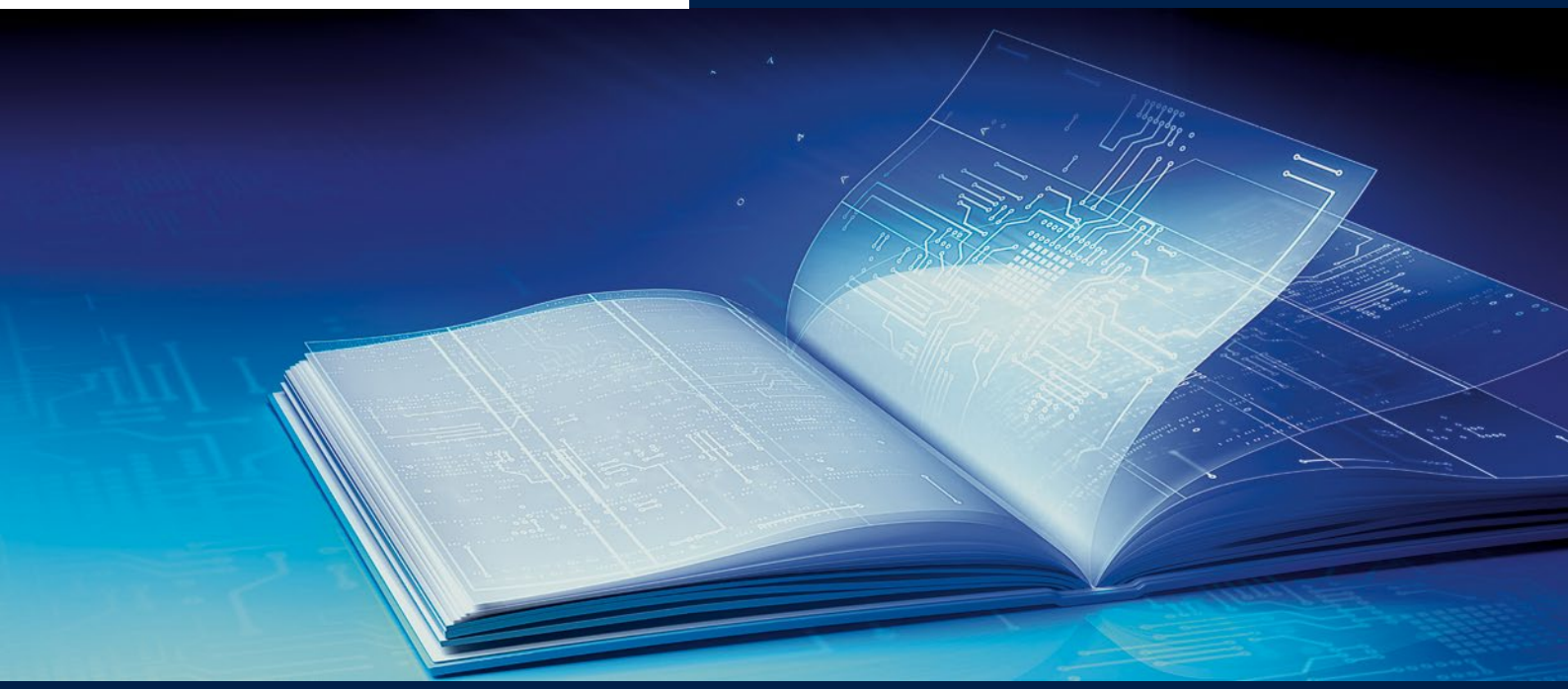

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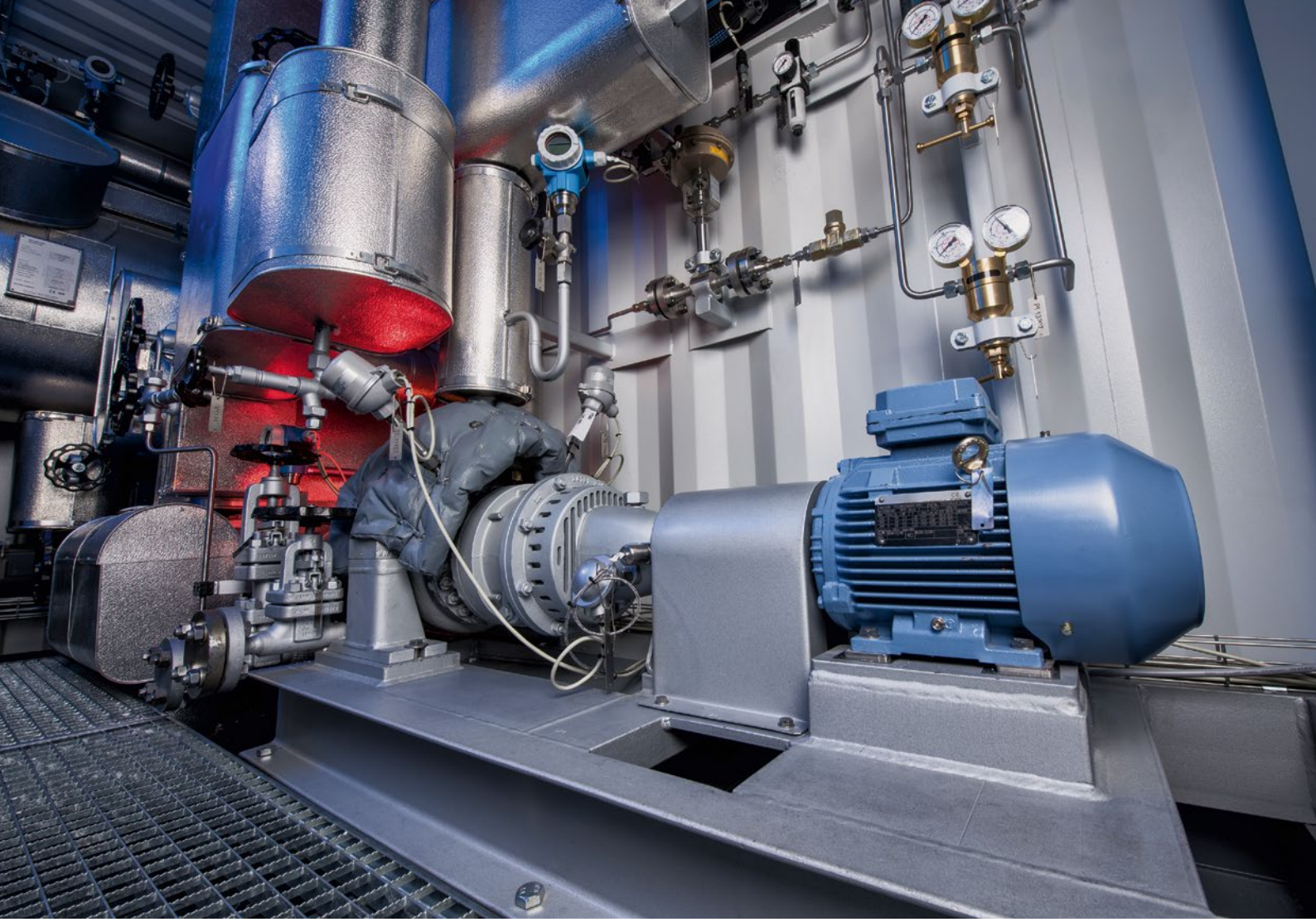


The magnetically coupled, self-venting pump operates reliable at temperatures of up to 500 °C. Source: CC-BY-SA DLR

Heat transition with concentrated solar thermal

Alexander Hammer

Industrial heat supply is responsible for a significant part of greenhouse gas emissions. But the days of fossil sources of energy are counted. Companies are recognizing more and more that they have a responsibility to the environment and at the same time can seize opportunities to remain competitive. Innovative technologies, alternative energy sources and new business models are ready. How can we make the transition from traditional heating methods to sustainable solutions? The heat transition in industry is more than just a technical changeover. This is the key to a sustainable, resource- efficient and future-proof economy.

Concentrated Solar Thermal (CST) is a key technology that uses mirrors to bundle sunlight in order to generate heat. Although the use of solar power is not a revolutionary new concept, CST differs from photovoltaic systems in providing heat directly instead of electrical energy. This particularly leads to a significant increase in the overall efficiency of the system when generating heat. There are two types of systems that are suitable for CST: parabolic trough- and linear Fresnel-constructions. Both types of systems consist of oblong, concave curved mirrors (parabolic troughs) or flat, narrow mirrors (Fresnel). They bundle the sunlight and effectively focus the solar radiation onto a receiver pipe that extends along a focal line. A heat transfer fluid that circulates through this pipe absorbs the concentrated heat and transfers it to a heat exchanger or directly to a consumer.

Gamechanger thermal heat store

The integration of thermal heat stores in concentrated solar thermal systems is a real game changer and opens up new possibilities for a sustainable supply of heating energy. By efficiently using solar energy to generate high temperatures, these systems can not only provide heat directly, but also store excess energy. Thermal energy storage systems enable the heat generated to release at a later date, which is particularly important at times when there is little or no solar radiation. This flexibility increases the security of supplies and enables better adaptation to energy requirements, particularly in industry and the building section. This not only makes the use of concentrated solar thermal more efficient, but also embeds it more consequently in an integrated energy system that supports the transition to a sustainable, renewable energy future.

The pump: live-giver for constructions and systems

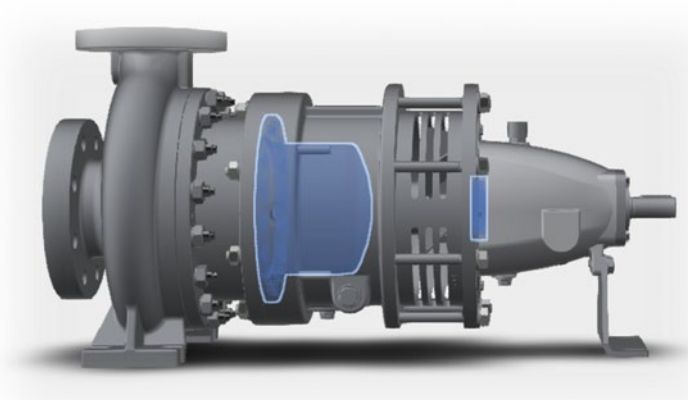
Pumps are essential in almost all industrial processes and act as the heart of these systems. Without them, today's standard of living would be almost unimaginable. From the industrial revolution through to the modern transition to sustainable climate neutrality - the use of pumps is crucial for the progress and efficiency of energy supply. They ensure, for example, that the retained heat arrives where it is needed, and are driving the transformation towards an emission-free future. Amidst of these rapid developments in pump technology, Dickow Pumpen from Waldkraiburg is contributing their 115 years of know-how. Due to the intensive research and development activities of the company based in Waldkraiburg, they are able to offer solutions that meet the challenges of today's industrial processes.

Thanks to containment shell of the magnetic coupling the medium is hermetically sealed to the environment.

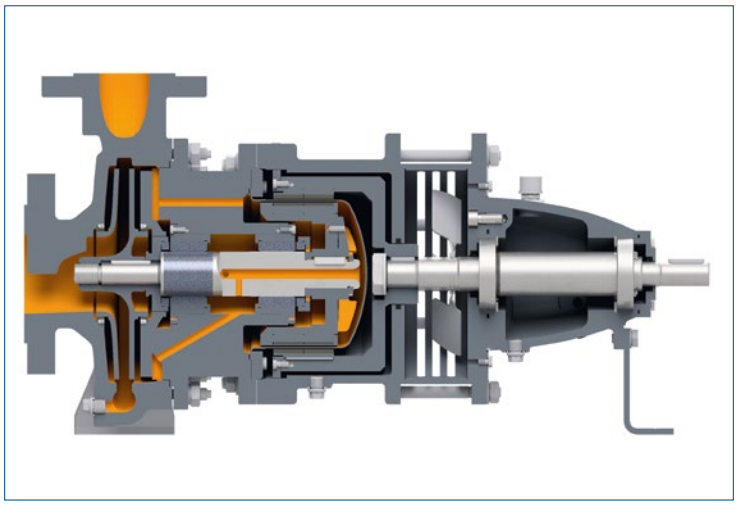
Efficient and robust in demanding applications

A new development from the manufacturer is a magnetic coupled and self-venting pump that has been specially developed for heat transfer applications. It was tested by the researchers of the German Aerospace Centre (DLR). It has the ability to handle temperatures of up to 500° C and pressures of 50 bar reliably in continuous operation without external cooling, and is therefore setting new standards in pump technology. This capability is based on the latest developments in magnet and materials tech-

Source: Dickow Pumpen



The cross section demonstrates the distance from containment shell to antifriction bearing.



Source: Dickow Pumpen

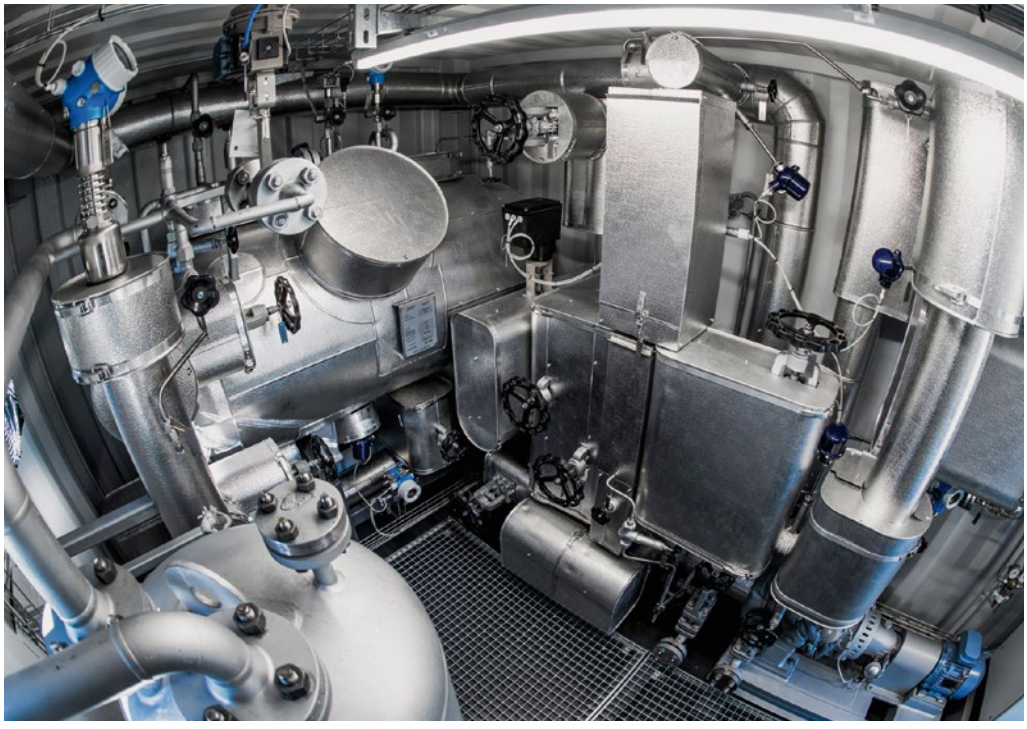
The graphic shows central components of the self-degassing centrifugal pump.

nology, which were previously considered unattainable. Through the harmonic combination of efficiency and robustness, the fluid flow machine makes a decisive contribution to the further development of sustainable industrial processes and positions itself as an indispensable tool in demanding applications.

The pumps have the ability for self-degassing and do not require any external cooling.

New silicone oils enable film temperatures of 460°C

Heat transfer oils enjoy great popularity in such applications - for very good reason: Their excellent ability to absorb heat with high efficiency makes them to a preferred choice in numerous industrial applications. In addition, they enable almost pressureless heat transfer over a wide temperature range, which makes them both versatile applicable and reliable. The series from the market leaders from Waldkraiburg, represents a new generation of heat transfer pumps that the manufacturer has developed particularly for use with all types of modern thermal oils. This magnetically driven centrifugal pump operates reliable and easily exceeds the high limits of use of conventional heat transfer pumps. A special feature is the ability for self-degassing as well as the waiving of any external cooling. This offers a pure plug-and-play solution that requires no additional installations and at the same time guarantees maximum safety against operating errors and cost-intensive machine downtimes.



Source: DLR

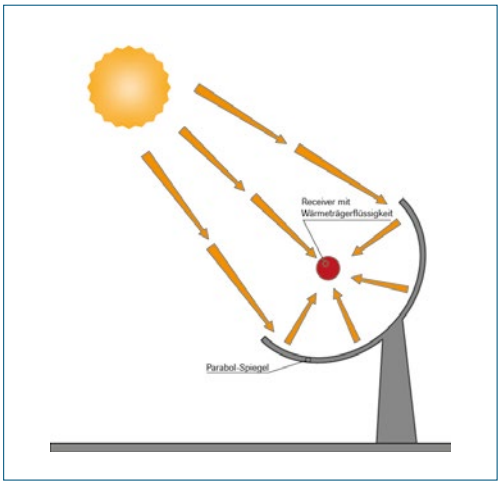
Researchers tested the pump at the DLR at pressures of 50 bar.

Increased operating safety

The design of the pump series also includes a hermetically sealed containment shell, which is located in a separate housing. In addition, a graphite safety packing provides a solid sealing to the atmosphere. If required, the pump can be equipped with a secondary mechanical seal and a leakage switch or other monitoring options, to reduce the leakage of the pumped liquid to an absolute minimum in the extremely unlikely case of a containment shell rupture. This not only guarantees the protection of human and environment, but also considerable increases the operating safety.

At very high temperatures or excess of age, heat transfer fluids tend to have poor lubricating properties – a real challenge for conventional magnetic drive pumps, which are dependent on sleeve bearings to fulfil their function. The thrust bearings are susceptible, as they quickly reach their limits under high loads. The new pump series takes this a step further. It automatically and completely compensates the axial thrust in the released performance curve range. The start-up rings therefore have additional backup for any unwanted operating conditions.

The operating temperature of antifriction bearings also has a significant influence on their operating life and capability. This is why the pump specialist has integrated a so-called fan flow deflector in the new series. The component between the magnetic coupling and the



Source: Dickow Pumpen

The graphic shows how concentrated solar thermal works.

Source: AdobeStock_718834169

Parabolic reflectors bundle the sunlight and effectively focus the solar radiation onto a receiver pipe.

roller bearings acts as a highly effective thermal barrier. This effectively ensures that the storage temperature always remains significantly below the critical values - even during continuous operation under extreme conditions. A reduction of the bearing temperature has an extremely positive effect on the operating life and the so-called Mean Time Between Maintenance (MTBM).

Active Flow Management

In addition, the developers have designed the magnet chamber of the pump to be directly flushed. It is critical that undesirable byproducts such as low-boiling separations or any nitrogen solubility cannot accumulate in the pump body.

In general, conventional hydrocarbon-based heat transfer fluids tend to change their chemical configuration and therefore their properties in the course of time. This decomposition depends on temperature and time. In modern silicone-based heat transfer oils, the solubility of nitrogen varied depending on temperature and pressure. With increasing temperature, the solubility of nitrogen rises significantly compared to other chemical substances. To secure that no byproducts accumulate in the pump design, the Dickow magnet pump is equipped with an active flow management system. This system provides an effective internal flow, that dissipates any gases and therefore lifts the efficiency and long-life cycle of the pump to a new level and nips potential breakdowns in the bud. This approach does not only eliminate risks, but also optimizes the performance and long-life cycle of the pump.

Minimal maintenance requirements

The pump series represents high efficiency with minimal maintenance efforts. The only maintenance effort that is required, is an oil change of the pump drive every 20,000 operating hours. The internal pump parts are wear-free and require no additional service. This significantly reduces the total cost of ownership (TCO) and makes the pumps to the ideal solu-

tion for users, who are looking for a long life cycle and minimal downtime. The manufacturer thereby offers a solution to the challenges that are associated with conveying heat carriers in combination with thermal energy storages. Due to their hermetical density, high temperature and pressure resistance as well as their energy efficiency and ease of maintenance, these pumps are suitable for use in complex applications and contribute to a successful heat transition.

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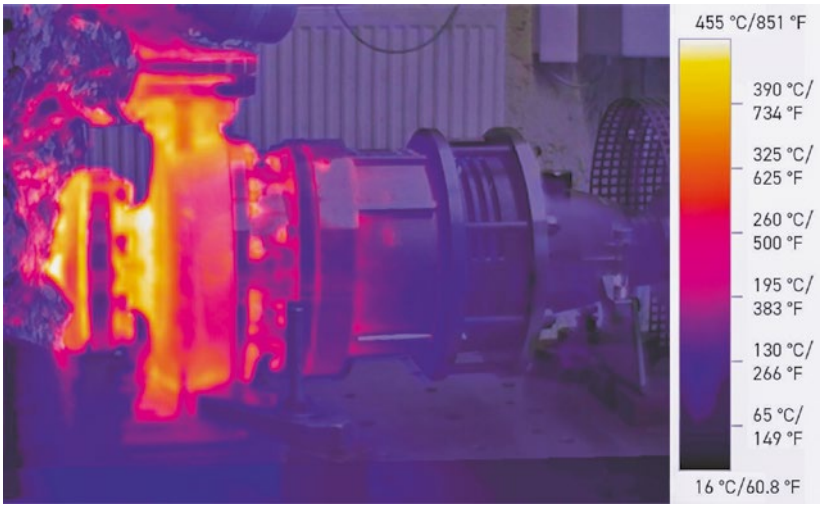

The magnetic coupled pump can handle temperatures of up to 500 °C. Source: Dickow Pumpen

The diaphragm metering pump is suitable for industrial applications such as chemical metering. Source: fotolia

New diaphragm metering pump: easy and robust

ProMinent GmbH

Easy and robust. These words encapsulate the concept for a new diaphragm metering pump. This development can be characterised by easy and intuitive operation. The pump is easy to commission and operate. It is also straightforward to install, maintain and recycle. In addition, the technology is robust and durable. Thanks to numerous improvements to the dosing heads, reliability and precision have been further increased compared to the previous model.

The new diaphragm metering pump from Heidelberg-based metering technology manufacturer ProMinent GmbH belongs to the medium-priced metering technology segment. It is available as a completely PFAS-free and fully recyclable version. The diaphragm metering pump allows for very precise dosing of liquid media in volumes from 10 millilitres to 50 litres per hour (0.0026 – 13 GPH). This range makes the metering pump well-suited for numerous applications.

Key fields of application

The diaphragm metering pump's main applications include water treatment and disinfection. It can also be used in evaporative cooling systems in which disinfectant solutions, corrosion inhibitors and antiscalants are added. Coating processes and chemical metering are other typical industrial applications, as well as building services, where the metering of phosphate solutions protects pipes.

Growing requirements for products in the mid-market segment

Customers have ever higher expectations of products in this highly competitive mid-market segment in particular. "There is increasing demand for displays and easy input options for setting the pump capacity, as well as bus systems for connecting to an automation system," summarises Rainer Kech, Director of Metering Technology at ProMinent GmbH.

The project team started with a blank sheet of paper and first surveyed customers to ascertain their requirements. The resulting wish list included not only easy operation, versatile application options and high precision, but also a small footprint, good display readability, reliable, safe operation and a long service life.

Focus on easy operation

In the second step, the development team set about clarifying what "easy operation" actually meant. It quickly became clear that the ability to directly input the metering volume in litres per hour was a key benefit for users. Direct input completely eliminates the complicated stroke and frequency calculations. Instead, the product itself performs settings in the background. The metering volume is entered by easy using a turn-push dial and the values appear on a display. "The easy, time saving input option gives our diaphragm metering pump a unique selling point in the mid-market segment," emphasises Kech.

It was already obvious during this development phase that there were even more aspects to the concept of simplicity: For the visualization of the status can also be made easier and safer for the user. As displays cannot be read from the front in many installation situations, status indication just via a front display is not the best solution. To resolve this, the three-colour LED status display of the new metering pump has been gently curved around the top edge. This means that the three LED lights can be easily seen by users from 360° and from a good distance away.

Solution for difficult-to-access installation situations

The development team also found an easy solution for installation and removal. A click system is fitted to the base of the diaphragm metering pump. Combined with a mounting plate that is fixed to the floor or wall, this enables easy installation and removal. Maintenance and repair work can therefore be carried out in no time, even in installation situations that are difficult to access.

Priming lift significantly increased

ProMinent extensively redesigned its liquid ends with the aim of greatly increasing precision compared to the previous model. The development team minimised the dead spaces and significantly improved the tightness of the valves. These measures have enabled the team to increase the suction lift to a considerable extent. The advanced pump now achieves a dosing precision of ± 1 % across its entire capacity range of 10 ml/h to 50 l/h. A positive side effect is that outgassing media such as sodium hypochlorite and viscous media up to 1000 mPas can also be metered much more precisely with the new model than with the previous one.

Source: ProMinent

Connection to cloud-based monitoring systems is quick and easy.

The pump covers the entire capacity spectrum from 10 millilitres to 50 litres per hour with just four dosing heads. The turndown ratio of one variant is 1-:-1000. Kech also sees this aspect of the development work as a simplification. “Usually, six to seven different pump versions are required to realise a diaphragm metering pump’s different metering volumes,” explains Kech. The reduction in the number of dosing heads streamlines the range of variants, and therefore also costs for procurement, warehousing and administration throughout the entire supply chain – distributors, integrators and users.

Viscous media up to 1000 mPas can be metered more precisely with this diaphragm metering pump than with the previous model.

Easy communication via Bluetooth and NFC

The diaphragm metering pump’s device and status information can be read contactless via an interface using Near Field Communication (NFC).

Bluetooth serves as a bidirectional interface. This enables more detailed programming of the pump and quick configuration of multiple pumps. Users can store various device configurations in their smartphone and then transfer the parameters contactless within Bluetooth range.

A digital universal slot is available for users who want to access the pump remotely. Any relays or fieldbus interfaces can be inserted into this slot. This gives users a quick and easy way to connect to cloud-based monitoring systems such as the Heidelberg manufacturer’s own web-based IIoT platform.

PFAS-free solution

In January 2023, the authorities of five European countries, including the German Environment Agency, submitted a dossier to the European Chemicals Agency (ECHA) with a proposal to restrict all per- and polyfluoroalkyl substances (PFAS). All manufacturers and users of appliances containing these substances would then have to find appropriate alternative solutions. The proposal stipulates that PFAS may only be used in products for which no suitable alternatives are available in the foreseeable future or for which the socio-economic advantages outweigh the disadvantages for people and the environment. For this reason, the development team decided to offer a PFAS-free version.

Which material is best?

In the search for alternative materials, manufacturers in this area are faced with a triad of requirements relating to chemical and mechanical resistance as well as costs. Materials such as

Source: ProMinent

Wall mounting is a breeze thanks to the mounting plate and click system.

Source: Adobe Stock

Water treatment is one of the main applications for the new diaphragm metering pump.

polyvinyl chloride (PVC), polypropylene (PP) and metal are not fully suitable due to their smaller range of chemical resistance. Fluoroelastomers such as FPM show weaknesses in mechanical durability, while ethylene-propylene-diene rubbers are not sufficiently resistant to common chemicals and therefore cannot be used universally. The material that shows the most promising properties on closer inspection is polyethylene (PE). Many chemical containers are made from this. It is chemically resistant and, depending on the type, also mechanically robust, ecologically harmless and cost efficient.

In diaphragm metering pumps, PFAS materials are mainly found in the dosing head, valve seals and diaphragms. In addition to chemical and mechanical resistance, other material properties also come into focus in these applications and are completely contrary to each other in some cases: the use in diaphragms, for example, requires a high degree of elastic deformability, while in the dosing heads the focus is on pressure stability, rigidity and dimensional accuracy, as well as shrinkage dimensions and tolerance precision.

By running a large number of trials, the Heidelberg development team succeeded in identifying suitable types and further optimising their technical properties for specific applications. Practical difficulties repeatedly arose during the development process. The connection between the PE diaphragm and the spindle was one example of many. There were frequent failures during user field testing. The decisive breakthrough came with the development of a special connection mechanism, for which a patent has since been filed.

The new diaphragm metering pump makes things easier for users at every stage of use. By dispensing with PFAS materials, it is also designed to be very sustainable and meets high ecological standards.

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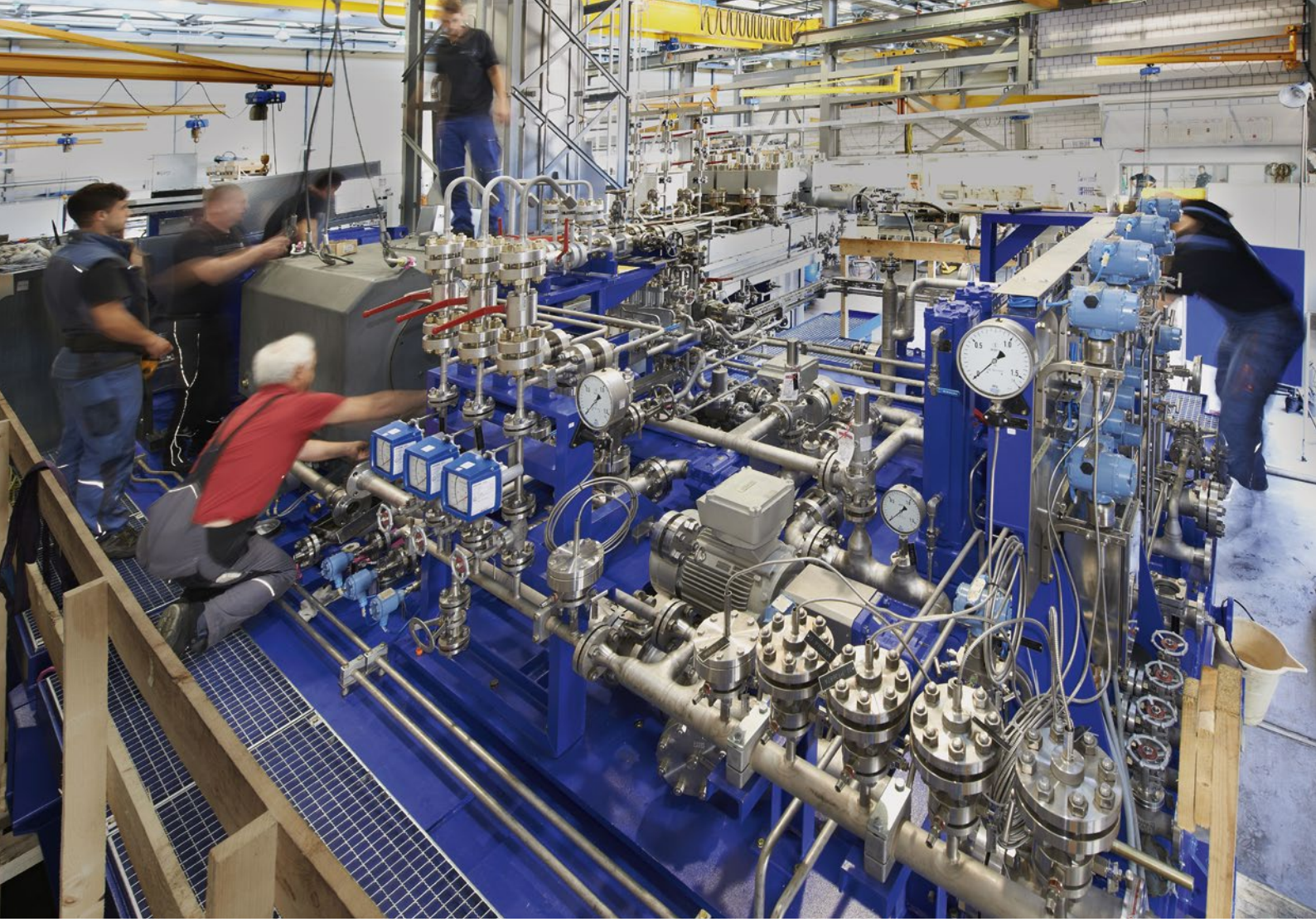


Liquid-sealed plunger pumps consume less than 0.1 per cent of additional energy and auxiliaries. Source: URACA

Liquid-sealed stuffing boxes for emission-free plunger pumps

Stephan Schmid

The first Technical Guideline for Air Quality (TA-Luft) was issued in 1895. Back then, the main focus was on building very tall chimneys to protect people and the environment from emissions on a regional level. It is not surprising that the current version of the guideline is much stricter and serves as a key component of plant regulations, defining permissible emission limits for operators. For plunger pumps, solutions have already been developed that make these pumps emission-free, helping to reduce harmful environmental and climate pollutants.

Unlike diaphragm pumps, plunger pumps are not explicitly mentioned in the TA-Luft guidelines for handling environmentally harmful fluids. As a result, users cannot automatically assume that plunger pumps will help meet the required emission standards. “Plant engineers and operators were increasingly unsure when making new investments. Can the requirements of the current Technical Guideline for Air Quality be met with plunger pumps? Does the system receive an operating permit in this way?,” reports Michael Lenz, URACA Head of Sales. This uncertainty prompted the high-pressure pump specialist to advance its plunger pumps, as they had already proven to be reliable in a variety of processes, both in terms of energy efficiency and maintenance intervals.

The goal of this development was to create a plunger pump that would be considered technically sealed in compliance with the regulations of TA-Luft and VDI 2440. The focus was not only on meeting the legal minimum requirements but also on maintaining high overall plant efficiency. To convince plant operators of the benefits of this type of pump, it was essential to retain the advantages of energy efficiency and long service life.

Function of a plunger pump

A plunger pump is a positive displacement pump. By crank drive it converts a rotary motion of a motor into a translational movement. Following this translational motion, plungers move back and forth between upper and outer dead center within several stuffing boxes. During the return stroke, the pump draws in the medium through a suction valve. On the forward stroke, it expels the medium through a discharge valve. The plunger is in direct contact with the medium and needs to be sealed against the stuffing box barrel.

Typically, a stuffing box contains two seals: the primary and secondary sealing. The primary sealing is exposed to the full operating pressure of the pump. Primary seals are often designed with packing rings, which are sized to leave a small liquid film on the plunger, preventing it from running dry and damaging the sealing. This liquid film is crucial because without it, excessive friction would build up between the plunger and the packing, leading to rapid wear of the primary sealing.

To capture the leakage from the primary sealing caused by this liquid film, a secondary sealing is located at the rear of the stuffing box. The secondary seal’s role is to remove the liquid film from the plunger and seal against any flushing fluid. This secondary sealing may also show some leakage, especially when pumps are continuously operated in tough industrial conditions over long periods. In standard plunger pump designs, this secondary leakage is collected in a dedicated leakage tray and the operator has to dispose it. However, the leakage tray is typically open to the atmosphere, allowing harmful media to escape and pollute the environment.

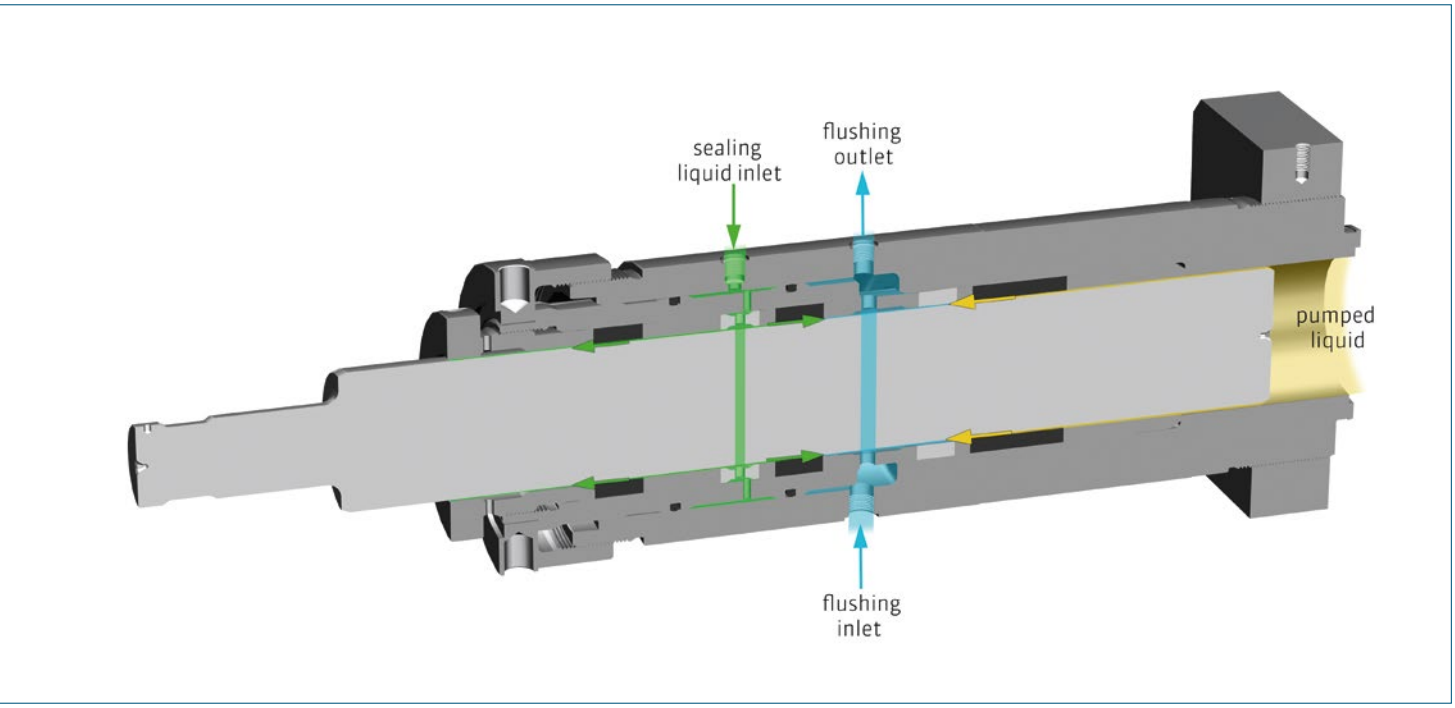
Due to the new liquid-sealing strategy, emissions from the pumped medium are not distributed throughout the entire pump – an advantage for flammable substances with ignition hazards.

Dynamic sealing as a challenge

In recent years, many plunger pump manufacturers have been working to certify their pumps for TA-Luft applications through notified bodies. The plunger pumps that have been tested and approved for TA-Luft compliance rely on the concept of sealing the entire pump as a closed unit. This means that operators need to collect and drain any leakages that inevitably occur within the pump in various ways.

Function of a plunger pump

Source: URACA



Source: URACA

The illustration shows fluid flows in a liquid-sealed stuffing box.

The biggest challenge in achieving a technically tight plunger pump design lies in ensuring the dynamic sealing of the translationally moving plunger. This issue can be avoided by expanding the sealing boundaries to the entire pump. Following this desing concept, the technically tight sealings can be shifted to other sealing areas. As a consequence, there is a significant increase in the number of sealing points which have to seal the pumped medium. Each of these sealing points increases the risk of potential seal failure and requires a monitoring of the seal condition.

Retrofitting liquid-sealed stuffing boxes, TA Luft compliance can also be achieved on existing systems.

Additionally it also requires significant modifications to components that may not originally be intended to be in contact with the fluid. This impacts both the pump's production costs and its maintenance intervals, as well as the service life of its wear parts.

Concept of the liquid-sealed stuffing box

The engineers at URACA focused on designing a liquid-sealed stuffing box by not treating the entire pump as a sealed system, but rather by making the individual components that contact the pumped liquid comply with TA-Luft regulations. They carefully considered every point where leakage might occur and ensured that leakage from the housing components, which contain the pumped medium, were completely prevented. As a result, the boundaries of the area, which has to be sealed in accordance to TA-Luft, is kept as small as possible. In this configuration, the plunger sealing is the only seal on a moving part in the entire liquid-contacting area. As described, in this part of the pump, leakage of the pumped medium occurs due to the type of sealing and due to drag flows created by the moving plunger. This leakage is necessary and cannot be completely eliminated. All other seals in this area are static seals, for which sufficient sealing solutions are available according to the current state of the art. They can already considered to be technically tight in standard configurations. The concept of the liquid-sealed stuffing box accepts the challenge of the dynamic plunger sealing and not only bypasses it.

This sealing strategy offers significant advantages to the operator. The emissions of the pumped fluid are not distributed throughout the entire pump, which is especially beneficial for flammable materials, reducing the risk of ignition. Additionally, the number of sealing systems that could potentially allow leakage due to malfunctions is minimized. This also simplifies monitoring of critical sealing systems, as the reduced number of seals and tightly defined system boundaries make it easier to track. If a seal fails, the user can shut down the pump in a controlled manner. Overall, this leads to lower investment and maintenance costs for operators while ensuring the long service life of the plunger pump.

Liquid-sealing prevents leakage

To prevent the secondary leakage from escaping into the atmosphere, the pump manufacturer has integrated an additional auxiliary system—the liquid-sealing—into the stuffing box. This system is arranged as the last auxiliary system of the stuffing box, directly behind a flushing system. By applying a sealing pressure significantly higher than that of the flushing system, a controlled liquid flow is directed from the liquid-sealing system to the flushing system. Similar principles are known, for example, in locked mechanical seals.

This controlled flow prevents the pumped fluid from escaping at the rear of the stuffing box. The leakage that occurs from the stuffing box consists only of the fluid from the liquid-sealing system. The pressure buildup in the sealing system is created by a pump that transports the sealing fluid to the stuffing box. Depending on the type of pressure generator, this piping system is also protected by an overflow or safety valve.

Monitoring differential pressure

The operation of this sealing concept depends on the differential pressure between the liquid-sealing system and the flushing system. This differential pressure is monitored using pressure sensors. If the pressure difference falls below a certain threshold, an alarm is triggered, or the system shuts down the pump. As

a result, operators can continuously monitor the functionality of the sealing system during both operation and downtime, ensuring high operational safety and compliance with emission limits. The system can be safely applied to all fluids for which chemically and thermally resistant sealing elements are available, and for which an appropriate sealing fluid is available at the plant site.

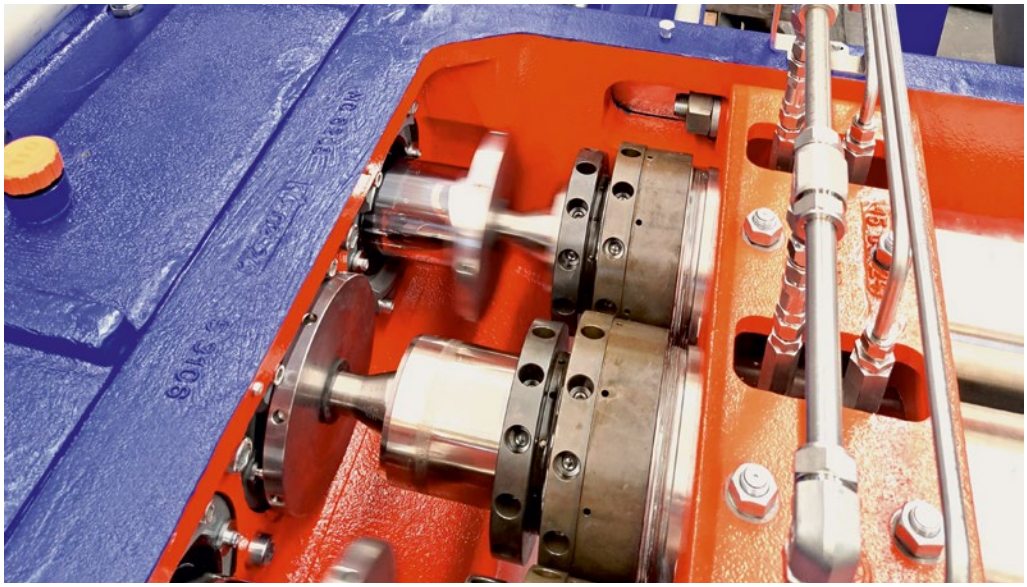
There are no restrictions on the types of pumped media.

Ammonia pump with liquid-sealing

Pungent smelling ammonia, a compound used in numerous chemical processes, is also regulated by the TA-Luft. To illustrate the consumption of the liquid-sealing system, it can be shown in relation to the consumption of the entire plunger pump system. Each pump unit is able to deliver 1,500 liters of liquid ammonia per minute at 250 bar operating pressure. With a suction pressure of around 20 bar, which is usual for ammonia applications, and overall efficiencies of more than 90%, the pump requires approximately 640 kW of electrical power.

The auxiliary system requires electrical energy to generate the pressure for the liquid-sealing. Since only small liquid-flows and pressures of 5 to 15 bar are needed to maintain the liquid-sealing, the hydraulic and electrical power required to operate this sealing pump is very low—under 300 watts, or just 0.05% of the total system power. As a result, this has almost no impact on the overall system efficiency.

In addition to the electrical power, the system consumes some sealing fluid. Practical experience has shown that between 10 and 50 liters of sealing fluid can be lost per day via the plunger sealing. While this might seem like a significant amount, it is negligible when comparing it to the flushing fluid required for the stuffing boxes and the cooling water needed for the drive and gearbox. In such powerful process pump systems, the cooling water demand may be up to 50 liters per minute. Comparing the consumption of auxiliaries, the liquid-sealed plunger pump requires less than 0.1% additional sealing fluid to maintain the liquid-sealing, making this extra consumption almost negligible for the operator. At the same time, the system contributes significantly to emissions reduction. Furthermore, TÜV Süd has certified that the liquid-sealed stuffing box complies with TA Luft and VDI 2440, which ensures the operator to receive the operating permit of the pump unit.



Source: URACA

Ignition hazard contained: Sealing strategy does not distribute emissions from the pumped fluid throughout the entire pump.

Sustainable Resource Management

The liquid-sealed stuffing box system can be retrofitted to existing plants, not just for new installations. Retrofitting an existing system is typically straightforward and is preferred from a sustainable business perspective compared to building a completely new pump system.

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Bad Urach

Source: URACA

Retrofitting to existing systems is generally possible without any problems.

Twin screw pumps are used on tankers for loading and unloading. Source: EPS Services and Sales B.V.

Twin screw pumps for “Ex zone 0 inside”

Jannik Meyer and Frank Holz

Liquid chemical and petrochemical products are produced, processed or consumed at various locations within the EU. These products are transported by road, rail or waterways. Transport on European inland waterways are governed by the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways, which was revised in 2019. This revision has tightened the requirements for explosion protection inside pumps. The inside of the pump must now meet the requirements for category 1 in order to be allowed to operate with an Ex-zone 0 inside.

Twin screw pumps are used in various industrial sectors to pump both high-viscosity and low-viscosity liquids as well as liquid-gas mixtures. They work on the principle of rotating displacement pumps. Their rotating, intermeshing feed screws transport the medium from the suction to the discharge nozzle of the pump. Ranges of application include the oil and gas industry as well as the chemical and pharmaceutical sectors. Flammable liquids are also often among the pumped media. Under certain operating conditions, for example when a tank containing a flammable liquid is emptied, an ignitable mixture can form within the pipeline and therefore also within the pump due to the admixture of ambient air.

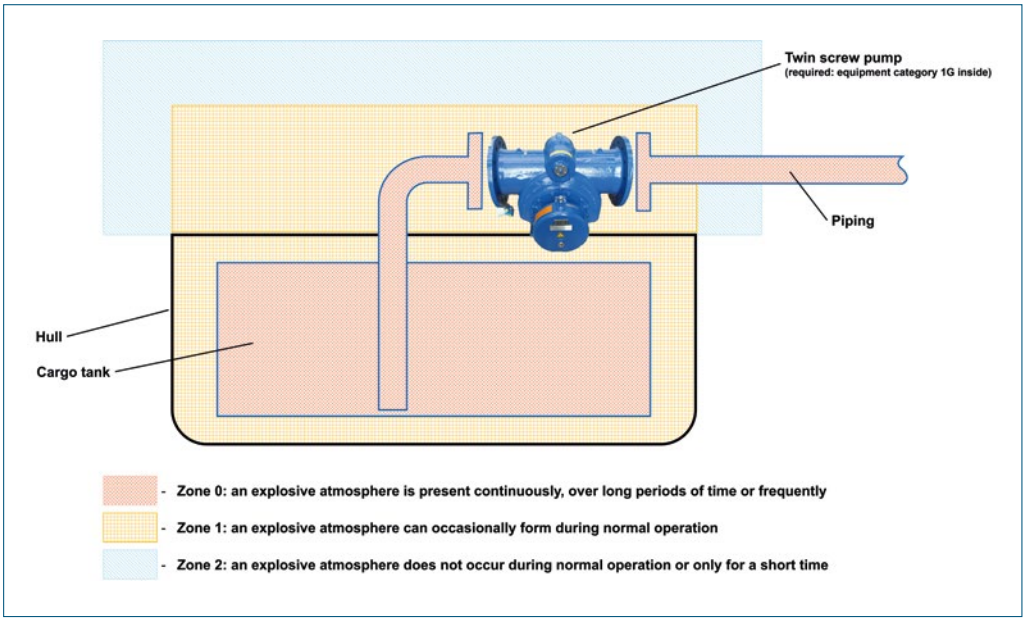
Conveying explosive liquid gas mixtures

The Directive 2014/34/EU, also known as the ATEX Directive, regulates the requirements that devices for use in potentially explosive atmospheres must meet in the European Economic Area. Here, explosive atmospheres are classified into Ex zones from 0 to 2 based on their probability and frequency of occurrence. Until now, the product portfolio of ITT Bornemann from Obernkirchen has included twin screw pumps that are suitable for use in Ex zones 1 and 2 inside the pump. This product portfolio has now been expanded to include a series that is also suitable for the permanent conveyance of explosive liquid gas mixtures ("Ex zone 0 inside" the pump). This series therefore complies with equipment category 1G internal in accordance with the ATEX directive and fulfills the highest level of safety.

Making ATEX-compliant pumps available

The drive to take this development step was provided by the revision to the "Accord européen relatif au transport international des marchandises dangereuses par voies de navigation intérieures" (ADN) 2019 agreement for inland waterway transport in the European Economic Area. The Obernkirchen-based company's twin screw pumps have been used for many years in large numbers on various tankers for loading and unloading, including on various inland waterway vessels in Europe. With the ADN 2019, the European Commission has made a change to the classification of explosive atmospheres in the pipelines of these ships. The previous classification for "Ex zone 1 inside" was tightened to "Ex zone 0 inside" when the ADN 2019 regulation came into force.

At that time, however, there were no suitable ATEX-compliant twin screw pumps on the pump market. As a result, the classification societies accepted that the previous pumps suitable for



Source: ITT Bornemann

The diagram illustrates the zones on a tanker in accordance with ADN 2019.

The European Agreement – ADN

The European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN) of May 26, 2000, which was signed by the United Nations Economic Commission for Europe (UNECE) and the Central Commission for the Navigation of the Rhine (CCNR), entered into force on February 29, 2008. With the ADN 2019, the current version of the regulation, which contains provisions on the transport of hazardous substances and the construction and operation of inland waterway vessels, was added to the Convention. To define certain regulations for different types of transported goods, these are divided into individual classes. Class 3, for example, includes flammable liquids. These include liquids such as petrol, cerosene and ethylene. The ADN 2019 regulates, among other things, which potentially explosive zones are to be defined in accordance with the ATEX Directive (2014/34/EU) in and around tanks, pipelines and equipment on tankers that transport such flammable substances.

Source: ITT Bornemann

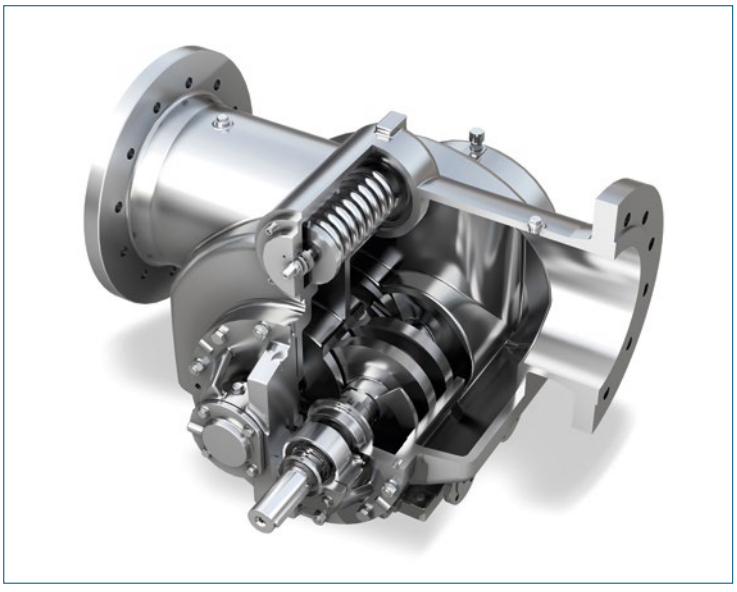
"Ex zone 1 inside", including additional safety-related instrumentation, could still be installed. The manufacturer then set itself the goal of closing this product gap in the market and qualifying some of its twin screw pumps for use in Ex zone 0 inside.

Focus on ignition hazards

In accordance with the ATEX Directive, series of non-electrical devices can be qualified for use in an Ex-zone 0 (device category 1), for example, by means of a type examination. To do this, the manufacturer must present their product, including technical documents and physical tests, to a notified body. This notified body specifies the content and scope of the tests to be carried out in order to verify sufficient safety. In order to ensure the continuous safe production of these "Ex-zone 0 inside" pumps, the notified body has audited and certified the quality assurance in the production process in accordance with module D of the ATEX directive.

With twin screw pumps, particular attention must be paid to explosion protection to:

- possible ignition sources due to mechanical friction,
- mechanically generated sparks caused by the contact of metallic components and
- the generation of compression heat.



Source: ITT Bornemann

The twin screw pump is protected by an internal recirculation valve.

Avoid hot surfaces

The conveying elements of the twin screw pumps operate without contact, the rotating spindles are synchronized by an oil-lubricated transmission. The build-up of differential pressure by the pump generates forces on the rotors that cause them to deflect. The stress field, formed by the explosion-proof pump and the hydraulically efficient pump, is created by selecting the gap widths between the rotating

Source: ITT Bornemann

As part of the type examination, the pumps were tested on the test bench in Obernkirchen.

conveying elements and the stationary housing. In the event of impermissibly high differential pressures and thus impermissibly high deflections of the spindles, contact could occur between the feed screws and the pump housing. This critical condition for explosion protection must be absolutely avoided under all operating conditions. A large gap width between the components would be a safe solution here. However, a large gap width results in poor hydraulic performance such as low volumetric efficiency and poor suction behavior. This is why the developers from Obernkirchen focused on this problem during product development.

However, certain components in the pump cannot operate without mechanical friction. These include the mechanical seals, which seal the pump's delivery chamber from the atmosphere. The way the mechanical seal operates means that the seal faces, separated only by a very thin film of liquid, rotate continuously against each

Source: ITT Bornemann

The marking for "Ex-zone 0 inside" in accordance with VDMA 24227 indicates the device category of the pump.

other. This rotation generates hydrodynamic friction in the gap, which leads to an unavoidable rise in temperature in the area of the seal faces. The maximum temperature rise had to be determined during development by means of test runs under different operating conditions and limited to a maximum permissible value. Sufficient lubrication and cooling of the seal faces must be ensured at all times to dissipate the frictional heat from the gap. As the "Ex-zone 0 inside" pumps are also intended for suction operation, it must be ensured that the sliding surfaces are supplied with lubricating fluid under these operating conditions.

In order to monitor the temperature increase caused by the compression heat during suction and rest operation, the pumps are equipped with a fitted sensor. This sensor only needs to be integrated into the control unit by the operator.

Source: ITT Bornemann

The pump and its accessories underwent a final inspection before delivery.

A solution through cooperation

In cooperation with external specialists for plant safety and explosion protection, the developers analyzed the new twin screw pump for the "Ex-zone 0 inside" with regard to the requirements of the ATEX directive and prepared a detailed risk assessment and ignition hazard evaluation. Together, they also prepared the technical documentation for testing by a notified body, in this case DEKRA.

Different sizes of the pump series were tested by DEKRA on the test bench in Obernkirchen. Over several days, the developers ran the twin screw pumps under different operating conditions and recorded a large number of measured values. In some cases, the pumps were tested far beyond their designed load limits to meet the high safety requirements. For example, the developers carried out a test run lasting several hours in cavitation mode to prove the robustness of the machines. By carrying out various test runs until the pump reached thermal stability in all planned operating scenarios, they were also able to prove that no unacceptably high temperature rises occur. After evaluation of the

measured values obtained by DEKRA, the certificate of conformity for the use of the pump with the “Ex-zone 0 inside” was issued.

With the successful completion of the development work and certification of conformity for use in “Ex-zone 0 inside”, twin screw pumps are now available that fully meet the requirements of ADN 2019. It is no longer necessary to apply for an exemption permit from classification societies for the use of twin screw pumps with equipment category 2G inside on inland waterway vessels.

Other ranges of application

In addition to tank shipping, the use of “Ex-zone 0 inside” pumps could also offer tank terminal operators increased explosion protection. These twin screw pumps could also be of interest to the chemical industry, which previously had to rely on other types of pumps to meet such high explosion protection requirements.

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An additional extruder continuously feeds the clean polymer melt in order to lubricate the bearing. Source: Maag Pump Systems

Polymer recyclate and polymers: New pump design extends service life

René Triebe

So-called post-consumer waste is becoming increasingly important as a source of raw materials. It usually has to be sorted first, as it tends to be mixed with harder impurities such as sand, glass splinters and metal foil residues. In the process of building up pump pressure, sealing is achieved either by contact surfaces or by very tight gaps. The foreign particles cause severe wear or seizing-up at those points, which can impair durability and lead to unplanned stoppages. New solutions improve robustness, extend service life, and expand the range of applications. The solutions are also suitable for highly filled polymers.

The circular economy is subject to enormous cost pressure, while the basic raw materials are currently often cheaper. Beyond that the processing of post-consumer waste is relatively costly. This is primarily because it is difficult to filter out the impurities to a sufficiently clean quality. Consequently, the final purity of the recyclate has a massive influence on the achievable price.

High-quality recycling of recovered raw materials

There are basically two different recycling concepts that make up a circular economy. The first is pure filtration, or mechanical recycling of the polymer mix, whereby the foreign particles are removed from the existing polymer melt. The achievable purity is however limited in this process. It is therefore often unsuitable for direct contact with foodstuffs, and for applications imposing higher demands.

The second concept, chemical recycling, depolymerizes the polymer chains in the recycling process. This process either produces a low-viscosity intermediate product or breaks the raw material down directly into partially gaseous streams. Polymer generated from these recovered raw materials is of high quality, and can be used without restriction. The process sequence is more complex than mechanical recycling, however.

Extending service life, avoiding sudden stoppages

Both process concepts are the same initially. The post-consumer waste must first be shredded, and manually precleaned to remove coarse impurities. The more tolerant the downstream process chain, the leaner the precleaning can be implemented. Significant wear along the entire process chain is a familiar aspect of post-consumer waste recycling, and it is completely normal for many components to need replacement every year or two. The end of life of wearing parts is usually signaled by changing process parameters such as rotation speeds or temperatures. So their replacement can be planned and coordinated with other maintenance work. Alongside the general requirement to extend service life, it is extremely important to avoid sudden stoppages and unplanned maintenance interventions.

Filler agglomerates block flow channels

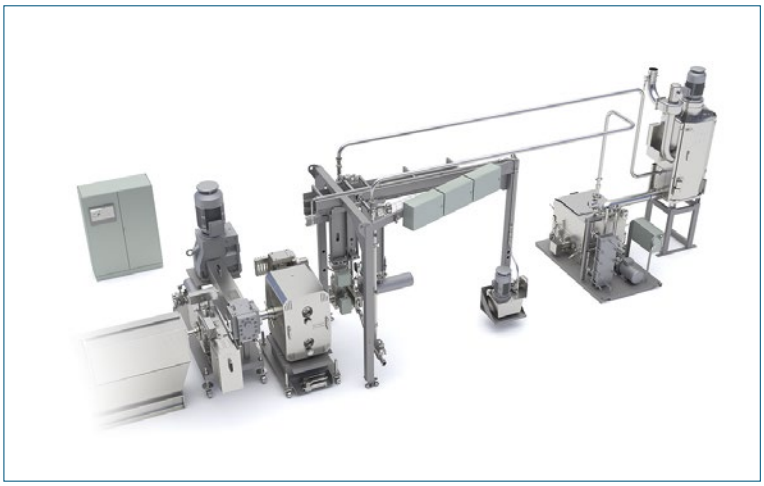
In highly filled mixes there are hardly any gaps between the fillers, and the interaction of the solids severely impedes the flow. Solids are repeatedly ground up in the flow, and the mix has limited flowability. Filler agglomerates behave similarly to impurities in recyclate, and can cause blockages. This is because the filler agglomerates tend to block flow channels – especially converging channels.

Higher concentrations can settle in converging flow channels, and the pressure pushes the polymer further out of the gaps between the filler particles, which further compacts the fillers, practically solidifying them. The pump is in effect blocked, usually without causing major damage. After cleaning – entailing a major disruption of the process – the pump can be run normally again.

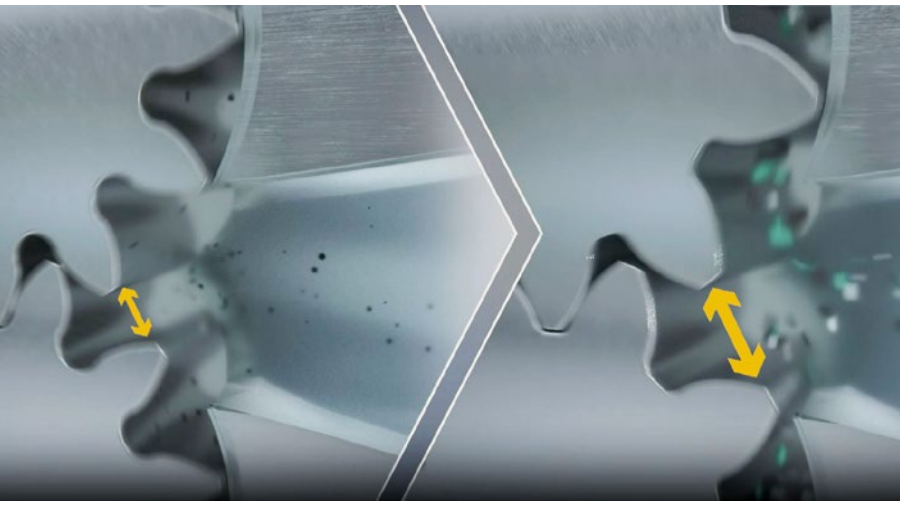
More robust design

The latest-generation of pumps from Maag feature a design that no longer collects dirt in an annular channel between the bearing and shafts. This means the new design is inherently

Source: Maag Pump Systems



With the system for recycling post consumer waste, users contribute to the circular economy.



Source: Maag Pump Systems

The special toothing to the right traps less polymer and leaves wider flow paths open.

less susceptible to damage from solid impurities, oversized fillers or high filler concentrations. This attribute has proved its worth right from launch.

Traditional gear pumps that have not yet been optimized for such applications have some problem areas that are at high risk if the pumped material is contaminated. The worst impact is from medium-sized ductile metal parts about 0.2 mm in size or larger (depending on pump size) being drawn into the slide bearing. This then leads to seizing-up of the shaft in the bearing: crushing, and ultimately melting, of the particle, which consequently melts and tears open the bearing and the shafts. In the worst case, cold welding occurs; the pump comes to an abrupt stop, and can no longer be used. In the best case, the surface is broken up, merely impairing the operating limits to some extent. This does, however, mean that even minor faults can stop the pump running.

Fewer teeth mean that the product is less compacted in the final meshing phase.

Gear pumps are generally optimized in terms of their bearings to work very reliably with a wide range of clean polymers. Because pure polymers in some instances have very extreme properties, good filling of the bearings is the main challenge in order to maintain a stable lubricating film. Recycling plants are always fed with a mixture, so the most extreme polymer properties such as melt breakage are not encountered. In particular, the mix contains various processing aids that have been added to counteract such phenomena. This opens up entirely new possibilities for the design of bearings.

Instead of allowing open access to the bearing, the manufacturer has incorporated a local filtration at the bearing lubrication inlet. A special geometry ensures that the bearing is still supplied with melt, but the larger particles are no longer drawn into the bearing gap. Whatever still gets in can cause only limited, minor wear. This does result in the bearing geometry being washed out over time, though without causing serious unforeseeable damage.

The service life of the interior components is normally limited by general wear, and end of life is signaled by a gradual decrease in efficiency. This means that the replacement of wearing parts can be planned and carried out together with other maintenance work. As opposed to traditional filtration systems with filter surfaces, the gap does not clog up, and the teeth carry the particles into an area of the bearing where, almost like a backwash filter, the dirt is pushed back out of the gap.

Service life extended

In an application in which the pump had a service life of around two to three weeks, the manufacturer was able to increase it to between 18 and 24 months by incorporating the filtering bearings. Above all, abrupt severe failure due to bearing seizure is now completely eliminated. This represents a massive improvement in terms of reliability and robustness, makes production plannable, and is essential to a cost-effective operation.

When processing highly filled polymers, filtration reduces the concentration of fillers in the bearing. The reduction in filler significantly improves the convergent bearing flow. This bearing design enables a higher filler concentration in the conveyed polymer melt than would otherwise be possible.

Greatly reduce pre-cleaning

If users are forced to generate very high pressures at very high temperatures, the filtering bearings are no longer sufficient for stable operation with the impurities in the post-consumer waste. In such applications, a solution involving external lubrication of the bearings is deployed. A small amount of clean polymer (about 0.5 – 1 percent) that is compatible with the process and of sufficient viscosity is injected into the bearings. This ensures that the shaft is supported securely. Mixing the lubricant into the process slightly increases the downstream flow rate. At first glance, such an approach appears costly. But this process can, in some cases, substantially reduce the required pre-cleaning, and so is economical for that reason alone.

Gear toothing made more robust

Another area in gear pumps that causes significant wear or blockages is the tooth meshing. When the second flank meshes, the remaining product stream must flow out via longer routes and through a narrower gap. Larger pieces of contaminant, in particular, can stick to the tooth root at this point, while the opposing tooth continues to engage further into the tooth space. These larger pieces are then pressed together into the remaining gap between the tooth head and root. The more the trapped volume has to be reduced, the greater the risk of blockage. To prevent this effect, the manufacturer uses a special toothing design with fewer teeth for recycling applications. Fewer teeth not only mean that the product is less compacted in the final meshing phase; there is also much more room for the product to flow out in the first meshing phase while the opposing tooth is engaging in the tooth space. This additionally reduces the loading on the gears due to lower squeezing pressures.

Wear usually occurs on the contacting tooth flanks where the driving shaft drives the rotating shaft. However, although the flank pressure increases due to the increased curvature of the optimized geometry, this new process means that far fewer particles are effectively trapped and ground between the flanks, and so the service life is extended.

Source: Maag Pump Systems

Extrusion system: Users can extend service life with timing gears.

Tooth flank wear significantly reduced

If the recyclate is so contaminated that the wear between the tooth flanks is unacceptable, users can install a timing gear between the reduction gear and the pump. This intermediate gear then drives both shafts simultaneously so that no torque transmission takes place in the pump, and the tooth flanks run practically contact-free. This significantly reduces tooth flank wear.

The introduction of filtering bearings has extended service life from 2 or 3 months to between 18 and 24 months.

Changing to an optimized gear geometry also has the advantage that the teeth are thicker and more robust. This means that even larger particles can only cause dents and deformations in the teeth; they will not usually break.

Flexible modular system improves circular economy

Pumps that prevent accumulation of dirt in the annular channel between the shaft and bearing are suitable as a basic system. Moreover, the filtering bearings in conjunction with the optimized gear toothing on the shafts cope well with medium degrees of contamination and medium filler concentrations, provided the required pressure is not too high.

If contamination is higher, users can counteract the primary wear in the tooth meshing by installing a timing gear. This makes sense where users want to maximize service life, or where replacement part costs exceed the investment in the timing gear.

There is also an option to lubricate the bearings externally. A small additional extruder is integrated into the system to continuously feeds the clean polymer melt to the pump in order to lubricate the bearing. This is the only way to

enable applications with higher pressures and thinner viscosities that would otherwise simply be inconceivable.

With these measures, users can make much more out of post-consumer waste, and so contribute to the circular economy. Even heavily contaminated waste collected from nature can increasingly be included, which increases the incentive for collection for recycling.

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Source: Maag Pump Systems

The extrusion pump can be equipped with a standard base frame for recycling applications.

Applications Pumps & Systems

	Water supply/wastewater disposal	Sewage engineering	Construction industry	Overhead irrigation	Irrigation	Well	Drainage	Garden	Groundwater conservation/lowering	Cellar drainage	Sewage treatment plant	Agriculture	Seawater desalination	Drainage, irrigation, lifting stations	Swimming-pool technology	Fountain	Deep well	Reverse osmosis	Water treatment	Mine drainage	Water supply	**Hygiene/cleanliness**	Biochemistry	Brewery	Dosing technology	Injection	Beverage industry	Cosmetics	Laboratory	Dairy	Food industry	Nuclear power station technology	Odorisation	Pharmaceutical industry	Sample taking	Sterile technology	**Industry-/chemical industry processes**
Alltech Dosieranlagen GmbH www.alltech-dosieranlagen.de		●									●		●						●		●				●								●				
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CP Pumpen AG www.cp-pumps.com													●										●	●		●	●	●			●	●	●	●		●	
Crane Process Flow Technologies GmbH www.cranecpe.com		●	●							●	●								●				●	●	●		●	●		●	●	●		●	●		
Deutsche Vortex GmbH & Co. KG www.deutsche-vortex.de																																				
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FLUX-GERÄTE GMBH www.flux-pumps.com		●	●								●	●			●				●				●	●	●		●	●	●	●	●			●			
Franz Eisele und Söhne GmbH & Co. KG www.eisele.de		●	●								●	●																								
FELUWA Pumpen GmbH www.feluwa.com		●	●				●			●	●												●		●		●	●		●	●			●			
Flowserve-Sterling SIHI GmbH www.flowserve.com		●	●	●	●						●		●	●				●	●		●		●	●		●	●				●	●		●			
FRISTAM Pumpen KG (GmbH & Co.) www.fristam.de																		●					●	●			●	●		●	●			●	●	●	
Gather Industrie GmbH www.gather-industrie.de											●		●					●	●		●		●	●	●		●	●	●	●	●			●	●	●	
GEA Group Aktiengesellschaft www.gea.com																		●	●				●	●		●	●	●		●	●			●	●	●	
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		●					●	●			●		●		●	●							Tank, container, barrel
●	●	●	●	●	●		●	●	●	●	●		●	●	●		●	●	●	●	●		Chemical industry
●	●		●				●	●		●	●		●	●	●		●	●	●	●			Draining
								●											●				Gas dehydration
	●							●		●					●				●		●		Gas washer
●		●		●	●		●	●		●	●		●	●	●	●	●	●	●	●	●		Industrial technology
	●						●	●		●	●		●	●		●		●		●	●		Surface treatment
●		●		●	●		●	●		●	●		●	●						●			Steel construction and vehicle construction industries
					●			●			●		●	●			●			●	●		Stone, earth and glass industries
	●	●	●	●			●	●		●	●		●	●	●		●	●	●	●			Storage tank installation
	●	●	●				●	●		●	●		●	●			●	●		●	●		Textile industry
●	●	●	●	●	●		●	●		●	●		●	●	●	●	●			●	●		Environmental technology
																							Building applications; heating and cooling
●		●		●				●			●					●		●	●	●			Pressure boosting
●				●			●	●			●							●	●	●			Fire-fighting system
●					●			●				●							●				Building controls and systems
●												●								●			Heating technology
●		●						●		●				●		●				●			Refrigeration and air-conditioning engineering
		●		●				●		●				●		●		●	●				Heat-transfer technology
																							Energy generation
		●		●			●	●	●	●				●				●	●	●			Energy engineering
●				●				●	●	●									●	●			District heating
								●										●	●				Firing technology
●				●				●	●	●					●				●				Geothermics
				●				●										●	●				Prime movers
		●		●	●			●	●		●		●		●				●	●	●		Power station technology
	●	●					●	●	●	●	●		●	●	●								Flue gas purification
																							Petrochemical; Oil
	●	●		●	●		●	●	●	●	●		●	●	●		●	●	●				Oil and petrochemical industry
	●	●			●			●	●	●				●	●		●	●	●	●			Off-shore technology
																							Mining; Metallury and rolling technology
		●			●		●		●				●	●					●	●			Mining
		●		●	●				●	●	●		●	●					●	●			Iron and steel industry
		●		●				●			●		●	●				●	●	●			Rolling-mills
									●														**Chemical engineering/Process technology**
●	●	●	●	●	●		●	●	●	●	●		●	●	●	●	●	●	●	●	●		Process engineering
●	●	●	●	●	●		●	●		●	●		●	●	●		●		●	●	●		Sugar industry
																							Oil supply/Hydraulics
																		●					Lift manufacturing
		●																●					Oil hydraulics
																		●					Centralized lubrication system
																							Testing
		●						●										●					Hydrostatic (pressure) test
																							Cleaning
●				●				●															High-pressure cleaning
																							Pulp and Paper
●	●	●	●	●	●	●	●	●	●	●	●	●		●	●			●			●	●	Paper and cellulose industry
																							Marine, shipyard technology
●	●	●	●	●	●		●	●	●	●	●			●				●	●	●	●	●	Marine, dockyard
							●	●								●							**Plastic production/processing**
								●							●								**Hydrogen technology**

Applications Pumps & Systems

	Water supply/wastewater disposal	Sewage engineering	Construction industry	Overhead irrigation	Irrigation	Well	Drainage	Garden	Groundwater conservation/lowering	Cellar drainage	Sewage treatment plant	Agriculture	Seawater desalination	Drainage, irrigation, lifting stations	Swimming-pool technology	Fountain	Deep well	Reverse osmosis	Water treatment	Mine drainage	Water supply	**Hygiene/cleanliness**	Biochemistry	Brewery	Dosing technology	Injection	Beverage industry	Cosmetics	Laboratory	Dairy	Food industry	Nuclear power station technology	Odorisation	Pharmaceutical industry	Sample taking	Sterile technology	**Industry-/chemical industry processes**
HAMMELMANN GmbH www.hammelmann.com													●					●						●			●			●	●			●			
Hauhinco Maschinenfabrik G. Hausherr, Jochums GmbH & Co. KG www.hauhinco.de			●																●												●					
Herborner Pumpentechnik GmbH & Co. KG www.herborner-pumpen.de		●	●		●		●			●	●			●	●	●			●		●		●	●			●		●	●						
HERMETIC-Pumpen GmbH www.hermetic-pumpen.com																		●					●	●			●	●		●	●			●			
HNP Mikrosysteme GmbH www.hnp-mikrosysteme.de																							●	●	●		●	●	●	●	●	●	●	●	●		
HOMA Pumpenfabrik GmbH www.homa-pumpen.de		●	●		●	●	●	●	●	●	●	●		●			●				●															
Jung Pumpen GmbH www.jung-pumpen.de		●	●		●	●	●	●	●	●	●	●		●		●	●				●															
KAMAT GmbH & Co. KG www.kamat.de		●	●			●					●	●	●				●	●					●		●	●			●		●	●		●			
KESSEL AG www.kessel.de		●					●			●																											
Klaus Union GmbH & Co. KG www.klaus-union.com													●										●									●		●			
KNF Neuberger GmbH www.knf.com		●									●								●			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Körting Hannover GmbH www.koerting.de		●											●						●								●				●					
KRACHT GmbH www.kracht.eu																									●				●			●				
KSB SE & Co. KGaA www.ksb.com		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●			●			●	●	●	●		●	
LEISTRITZ Pumpen GmbH www.leistritz.com																							●	●	●	●	●	●		●	●		●				
LEWA GmbH www.lewa.com																							●	●	●	●	●	●	●		●		●	●			
Maag Germany GmbH www.maag.com																							●		●			●	●		●		●	●			
Maag Witte GmbH www.maag.com																							●		●			●	●		●			●			
Mahr Metering Systems GmbH www.mahr.com																									●	●		●	●		●			●			
MATO GmbH & Co. KG www.mato.de																																					
Munsch Chemie-Pumpen GmbH www.munsch.de		●											●						●															●			
NETZSCH Pumpen & Systeme GmbH www.pumps-systems.netzsch.com		●	●		●	●	●		●	●	●	●	●	●			●	●	●	●	●		●	●	●	●	●	●		●	●	●		●	●	

●		●	●	●	●			●	●		●				●						●	Tank, container, barrel
●	●		●	●	●	●	●	●	●	●	●	●		●		●	●	●	●		●	Chemical industry
●	●		●	●	●		●	●	●	●	●	●			●	●			●			Draining
								●			●							●			●	Gas dehydration
●	●							●		●	●	●						●			●	Gas washer
●	●			●	●		●	●	●		●	●		●		●	●		●	●		Industrial technology
●	●		●					●	●		●			●			●	●	●		●	Surface treatment
●	●		●				●	●	●		●			●					●	●	●	Steel construction and vehicle construction industries
●								●			●								●			Stone, earth and glass industries
●	●	●			●		●		●	●	●	●						●				Storage tank installation
●			●	●	●		●	●		●	●			●						●	●	Textile industry
●	●	●			●	●		●	●	●	●	●		●		●	●	●	●	●	●	Environmental technology
																						Building applications; heating and cooling
●			●	●	●	●	●	●	●		●				●				●			Pressure boosting
							●	●						●					●			Fire-fighting system
								●							●	●			●			Building controls and systems
								●			●								●			Heating technology
							●	●	●		●	●		●				●	●			Refrigeration and air-conditioning engineering
							●	●	●			●						●	●			Heat-transfer technology
																						Energy generation
●								●	●		●	●		●				●	●			Energy engineering
								●														District heating
											●							●				Firing technology
							●	●		●		●		●				●		●	●	Geothermics
●							●		●													Prime movers
●	●						●	●	●	●	●	●						●		●		Power station technology
●	●							●		●	●	●						●				Flue gas purification
								●														**Petrochemical; Oil**
●		●	●	●	●	●	●	●	●	●	●	●		●			●	●	●	●	●	Oil and petrochemical industry
●			●	●	●	●	●	●	●	●		●	●	●					●	●	●	Off-shore technology
																						Mining; Metallury and rolling technology
●	●	●					●	●	●		●			●						●	●	Mining
●	●							●			●			●						●	●	Iron and steel industry
●	●				●		●	●	●					●					●	●	●	Rolling-mills
								●														**Chemical engineering/Process technology**
●	●		●	●	●	●	●	●	●	●	●	●	●	●				●	●	●		Process engineering
●	●			●	●		●	●		●	●	●	●	●					●		●	Sugar industry
																						Oil supply/Hydraulics
●																						Lift manufacturing
●				●	●		●		●			●		●							●	Oil hydraulics
●		●			●		●		●			●										Centralized lubrication system
																						Testing
●									●		●			●						●	●	Hydrostatic (pressure) test
																						Cleaning
●														●						●	●	High-pressure cleaning
																						Pulp and Paper
●			●		●	●	●	●	●	●	●	●		●				●	●	●	●	Paper and cellulose industry
																						Marine, shipyard technology
●			●				●	●	●	●	●	●		●		●		●	●	●	●	Marine, dockyard
					●												●					**Plastic production/processing**
●								●			●			●			●					**Hydrogen technology**

Applications Pumps & Systems

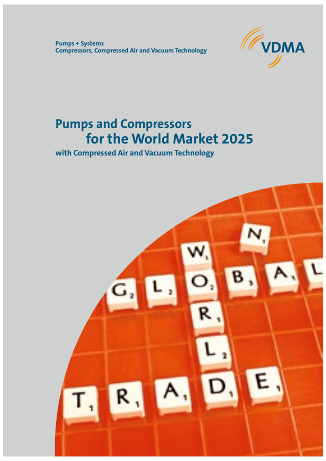
	Water supply/wastewater disposal	Sewage engineering	Construction industry	Overhead irrigation	Irrigation	Well	Drainage	Garden	Groundwater conservation/lowering	Cellar drainage	Sewage treatment plant	Agriculture	Seawater desalination	Drainage, irrigation, lifting stations	Swimming-pool technology	Fountain	Deep well	Reverse osmosis	Water treatment	Mine drainage	Water supply	**Hygiene/cleanliness**	Biochemistry	Brewery	Dosing technology	Injection	Beverage industry	Cosmetics	Laboratory	Dairy	Food industry	Nuclear power station technology	Odorisation	Pharmaceutical industry	Sample taking	Sterile technology	**Industry-/chemical industry processes**
oddesse Pumpen- und Motorenfabrik GmbH www.oddesse.de		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●			●			●				●						
Oerlikon Barmag, Zweigniederl. der Oerlikon Textile GmbH & Co. KG www.oerlikon.com/polymer-processing		●									●	●						●	●				●	●	●	●	●	●	●	●	●			●			
ORPU Pumpenfabrik GmbH www.orpu.de		●	●	●	●	●	●	●		●	●	●							●		●															
OSNA-Pumpen GmbH www.osna.de			●	●	●	●	●	●	●	●	●	●					●	●	●	●	●																
PCM Deutschland GmbH www.pcm.eu		●	●				●				●								●		●		●	●	●	●	●	●		●	●			●	●		
PF Pumpen und Feuerlöschtechnik GmbH www.johstadt.com		●				●					●								●				●	●	●		●	●		●	●						
Ponndorf Gerätetechnik GmbH www.ponndorf.com		●	●								●								●		●			●	●		●	●	●	●	●			●	●		
ProMinent GmbH www.prominent.com		●		●	●	●	●				●	●	●		●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●			
Pumpenfabrik Wangen GmbH www.wangen.com		●	●								●	●		●					●				●	●	●	●	●	●	●	●	●	●	●	●			
REBS Zentralschmiertechnik GmbH www.rebs.de											●			●										●	●	●	●										
ITT Rheinhütte Pumpen GmbH www.rheinhuette.de		●									●		●						●				●											●			
Richter Chemie-Technik GmbH www.richter-ct.com		●									●		●						●				●	●			●				●			●			
Rickmeier GmbH www.rickmeier.de																																					
Schmalenberger GmbH + Co. KG www.schmalenberger.de		●		●	●		●	●	●	●	●	●		●	●				●		●		●		●				●					●			
SERO PumpSystems GmbH www.seroweb.com				●	●								●					●	●	●	●		●	●			●	●			●	●		●			
SKF Lubrication Systems Germany GmbH www.skf.com/schmierung		●	●								●	●												●	●	●	●				●						
SPECK Pumpen Verkaufsgesellschaft GmbH www.speck-pumps.com		●		●	●	●	●	●	●	●		●			●	●	●	●	●		●			●			●			●					●		
STOZ Pumpenfabrik GmbH www.stoz.com																																					
Sulzer Pumpen (Deutschland) GmbH www.sulzer.com		●					●		●		●		●	●				●	●	●	●										●						
Tsurumi (Europe) GmbH www.tsurumi-europe.com		●	●	●	●		●	●	●	●	●	●		●	●	●	●		●	●	●			●			●			●	●					
URACA GmbH & Co. KG www.uraca.de		●									●		●					●			●			●		●	●			●	●		●			

●	●						●			●	●	●	●		●	●			●	●	Tank, container, barrel
●	●			●	●	●	●		●	●	●	●	●		●	●	●		●	●	Chemical industry
	●			●	●	●	●		●	●		●	●		●	●	●		●	●	Draining
●										●											Gas dehydration
●				●					●	●			●								Gas washer
●	●			●	●	●	●	●	●	●	●	●	●			●	●		●	●	Industrial technology
●				●	●		●		●	●	●	●	●			●			●		Surface treatment
●					●	●	●	●	●	●	●	●	●			●	●		●		Steel construction and vehicle construction industries
	●				●	●	●			●	●	●	●		●	●					Stone, earth and glass industries
				●	●	●	●	●	●	●		●	●				●		●		Storage tank installation
●				●	●	●	●			●	●	●	●			●	●		●		Textile industry
●	●			●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	Environmental technology
																					Building applications; heating and cooling
●				●		●	●										●	●	●	●	Pressure boosting
				●		●										●	●			●	Fire-fighting system
	●			●									●				●	●		●	Building controls and systems
				●																	Heating technology
				●		●											●				Refrigeration and air-conditioning engineering
				●		●	●						●								Heat-transfer technology
																					Energy generation
●			●			●				●			●				●			●	Energy engineering
		●											●							●	District heating
																	●				Firing technology
●		●				●						●	●							●	Geothermics
			●					●													Prime movers
●	●	●			●	●			●	●	●		●			●					Power station technology
●		●		●		●			●	●			●								Flue gas purification
																					Petrochemical; Oil
●		●			●	●	●	●	●	●		●	●	●	●	●	●		●		Oil and petrochemical industry
●	●	●			●	●		●					●			●	●	●		●	Off-shore technology
																					Mining; Metallury and rolling technology
●	●	●			●				●	●	●		●		●	●	●			●	Mining
●	●	●			●		●			●	●		●			●	●			●	Iron and steel industry
●	●	●			●			●		●	●		●			●	●		●	●	Rolling-mills
																					Chemical engineering/Process technology
●		●		●	●	●	●		●	●		●	●	●	●	●	●		●	●	Process engineering
●		●			●	●			●	●	●	●	●		●	●			●		Sugar industry
																					Oil supply/Hydraulics
											●										Lift manufacturing
●																			●		Oil hydraulics
			●		●		●	●			●		●			●			●		Centralized lubrication system
																					Testing
●		●																			Hydrostatic (pressure) test
																					Cleaning
●	●			●			●				●	●	●				●				High-pressure cleaning
																					Pulp and Paper
●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●		●		Paper and cellulose industry
																					Marine, shipyard technology
●	●	●		●	●	●		●			●	●	●		●	●	●	●	●	●	Marine, dockyard
									●										●		**Plastic production/processing**
									●				●						●		**Hydrogen technology**

Applications Pumps & Systems

	Water supply/wastewater disposal	Sewage engineering	Construction industry	Overhead irrigation	Irrigation	Well	Drainage	Garden	Groundwater conservation/lowering	Cellar drainage	Sewage treatment plant	Agriculture	Seawater desalination	Drainage, irrigation, lifting stations	Swimming-pool technology	Fountain	Deep well	Reverse osmosis	Water treatment	Mine drainage	Water supply	**Hygiene/cleanliness**	Biochemistry	Brewery	Dosing technology	Injection	Beverage industry	Cosmetics	Laboratory	Dairy	Food industry	Nuclear power station technology	Odorisation	Pharmaceutical industry	Sample taking	Sterile technology	**Industry-/chemical industry processes**
Vogelsang GmbH & Co. KG www.vogelsang.info		●	●	●	●	●	●		●	●	●	●	●	●	●		●	●	●		●		●	●			●	●		●	●	●		●			
ViscoTec **Pumpen- u. Dosiertechnik GmbH** www.viscotec.de																							●	●	●	●	●	●	●	●	●			●		●	
Wepuko PAHNKE GmbH www.wepuko.de																					●		●			●					●	●		●			
WERNERT-PUMPEN GMBH www.wernert.de		●									●		●					●	●				●													
WILO SE www.wilo.com		●	●	●	●	●	●	●	●	●	●	●		●		●	●		●	●	●		●	●			●			●	●			●		
WITA – Wilhelm Taake GmbH **Pumpen-, Armaturen- und Regeltechnik** www.wita-taake.de															●												●				●						
Eugen WOERNER GmbH & Co. KG www.woerner.de		●	●								●	●		●					●		●			●	●		●				●			●			
WOMA GmbH | Kärcher Group www.woma-group.com		●	●										●					●			●															
Xylem Water Solutions **Deutschland GmbH** www.xylemde		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●		●	●		

Tank, container, barrel	●	●					●	●	●
Chemical industry	●	●	●	●	●		●	●	●
Draining	●	●		●			●		●
Gas dehydration			●	●				●	
Gas washer	●	●	●	●	●			●	●
Industrial technology	●	●	●	●			●	●	●
Surface treatment	●	●	●	●				●	●
Steel construction and vehicle construction industries	●	●		●	●		●	●	●
Stone, earth and glass industries	●	●			●		●		
Storage tank installation	●	●		●					●
Textile industry	●	●	●		●		●	●	●
Environmental technology	●	●	●	●	●		●		●
Building applications; heating and cooling									
Pressure boosting	●	●	●		●			●	●
Fire-fighting system	●	●			●				●
Building controls and systems	●	●			●	●			●
Heating technology					●	●			●
Refrigeration and air-conditioning engineering					●	●			●
Heat-transfer technology					●	●			●
Energy generation									
Energy engineering	●		●		●				
District heating					●				●
Firing technology									
Geothermics			●		●			●	●
Prime movers	●						●		
Power station technology	●		●	●	●		●		●
Flue gas purification	●			●			●		●
Petrochemical; Oil									
Oil and petrochemical industry	●		●	●	●		●	●	●
Off-shore technology	●		●		●		●	●	●
Mining; Metallury and rolling technology									
Mining	●			●	●		●	●	●
Iron and steel industry	●		●	●	●		●	●	●
Rolling-mills	●		●	●	●		●	●	●
Chemical engineering/Process technology									
Process engineering	●	●	●	●			●		●
Sugar industry	●	●		●			●	●	●
Oil supply/Hydraulics									
Lift manufacturing							●		
Oil hydraulics			●				●		
Centralized lubrication system			●				●		
Testing									
Hydrostatic (pressure) test	●		●		●			●	●
Cleaning									
High-pressure cleaning			●					●	●
Pulp and Paper									
Paper and cellulose industry	●		●	●	●		●	●	●
Marine, shipyard technology									
Marine, dockyard	●		●	●	●		●	●	●
Plastic production/processing	●				●				
Hydrogen technology			●		●				



The compressors store CO_2 in depleted gas caverns or convert it into synthetic fuels. Source: Stefan Hobmaier / MAN Energy Solutions

Modular decarbonization with integrally-geared compressors

Florian Bohnenkamp

Achieving net-zero emissions is the goal – but how do we implement decarbonization in CO_2-intensive industries? This is a critical question for companies in so-called “hard-to-abate” sectors, including the process, chemical, and cement industries, as well as operators of coal and gas-fired power plants essential for electricity generation and the ramp up of hydrogen (H_2) production. Fortunately, carbon capture, utilization, and storage (CCUS) technologies have reached a level of maturity that now allows for effective, modular solutions – featuring geared compressors and advanced digital tools – that can help meet climate targets.

In May 2024, the European Union (EU) adopted the "Net Zero Industry Regulation", a legally binding framework to decarbonize European industries. This regulation aims to develop and deploy key technologies necessary for achieving the EU's climate neutrality targets. Regulation (EU) 2024/1735,40, Page 10/63 of the European Parliament and Council states: "Full and individual CCS value chains including capture, transport and storage need to be established by 2030 via effective Union and national politics with appropriate regulations guaranteeing competition and open access." Compressors play a central role in this emerging global market, with fast, proven, and cost-effective solutions now available.

Technologies for Avoiding CO_2: Developed in the Blink of an Eye

Each industry has specific needs and challenges related to climate targets. Moreover, legal requirements now mandate a reduction or elimination of greenhouse gas emissions. Achieving net-zero emissions within the next 25 years demands standardized technologies and approaches across the global value chain. Among the most urgent investments are those in CO_2 capture and compression, which are critical to safeguarding operations.

It may sound conventional, but the development of CO_2 compression technologies began as early as the 1980s with leading compressor manufacturers. Since then, the learning curve has been steep – and is still evolving today. This extensive knowledge base forms the foundation for rapidly developing, certifying, and deploying technologies for CO_2 capture, compression, storage, transport, and reuse across various industries.

Thermodynamics: Understanding the CO_2 Compression Process

At standard conditions (0°C and 1.01325 bar), CO_2 is a colorless, odorless gas with a molar mass of 44.0095 g/mol. When pressurized to 70 bars, the gas's volume is reduced to just 1 per cent of its original size. CO_2 becomes a "supercritical fluid" under these conditions, meaning its physical properties change when subjected to high pressure and heat. In its supercritical state, CO_2 behaves both like a liquid (in terms of solubility) and a gas (in terms of diffusivity).

The key challenge in CO_2 compression lies in controlling the critical parameters – pressure, temperature, flow rate, and dwell time – in the compression stages. As the gas moves through the compressor stages, pressure is increased, and the heat generated is dissipated to allow for further compression with reduced energy requirements.

A key risk during the cooling phase is the potential for CO_2 to liquefy, forming carbonic acid, which can be corrosive and damage compressor components. To prevent this, the design of the cooler (heat exchanger) is critical. Optimizing the speed of compressor stages improves performance: due to the significantly reduced volume of CO_2, smaller blades are needed, which operate more efficiently at higher speeds. This is why geared compressors are ideally suited for such demanding applications.

The new compressor solution for carbon capture uses significantly less energy compared to traditional systems.

The Global Impact of Modular CCUS Systems

Globally, the top 25 per cent of CO_2-intensive industrial companies are responsible for between 1 and 10 MTPA of CO_2 emissions annually. These major emitters contribute to more than 85 per cent of global cumulative stationary CO_2 emissions. Given that CO_2 concentrations typically remain below 20 per cent and emissions are usually at or slightly above atmospheric pressure, these relatively stable operating conditions are ideal for developing modular CCUS technologies.

Modular and Cost-Optimized Solutions for Industrial CO_2 Capture

Radial multi-shaft integrally-geared compressors (RG) are capable of handling volume flows ranging from 0.4 to 2.75 million tons of CO_2 per

Source: MAN Energy Solutions

In the CCUS compressor system, an RG compressor is integrated.

Commissioning in remote and hard-to-reach locations can be optimally planned and executed with reliability.

year (MTPA). Currently, the most commonly used platform compresses up to 1 MTPA, and the market potential for these solutions is enormous. These modular systems are versatile enough to handle gaseous, liquid, and supercritical CO_2 without significant modifications to the compression system, covering the full performance range required by current and future carbon dioxide regulations.

The modular design significantly simplifies project planning, reducing complexity for customers. Shorter delivery and installation times further reduce planning requirements. Additionally, lower production costs from manufacturers result in reduced investment volumes, making these solutions more cost-effective. These advantages also make it easier to deploy compressor systems in remote or challenging locations.

Digital Process Optimization and Virtual Commissioning

Digital tools have made it possible to simulate and optimize the performance of geared compressors before physical installation. Virtual commissioning allows key parameters, such as driving characteristics and control behaviors, to be tested and refined. This simulation creates greater certainty for system operators during the initial phase of the carbon capture project, as they learn to manage:

- The startup process of newly integrated CO_2 compressors
- Critical phases of the compression process
- The condition of compressed CO_2 at the end of the process

Source: Heidelberg Materials Norway

For the first time, the new CCHR technology will be deployed in Brevik.

Artificial intelligence (AI) can also be integrated for continuous process monitoring. AI-driven systems learn from real-time data and can immediately alert operators if the system deviates from optimal performance. The maintenance cycles for these systems align with regular operational check-ups, typically occurring every five years. For predictive maintenance, the appropriate sensor technologies can be used to gather and analyze data, ensuring that systems operate smoothly and efficiently. As CO_2 credit prices rise, the demand for such monitoring technologies will likely increase.

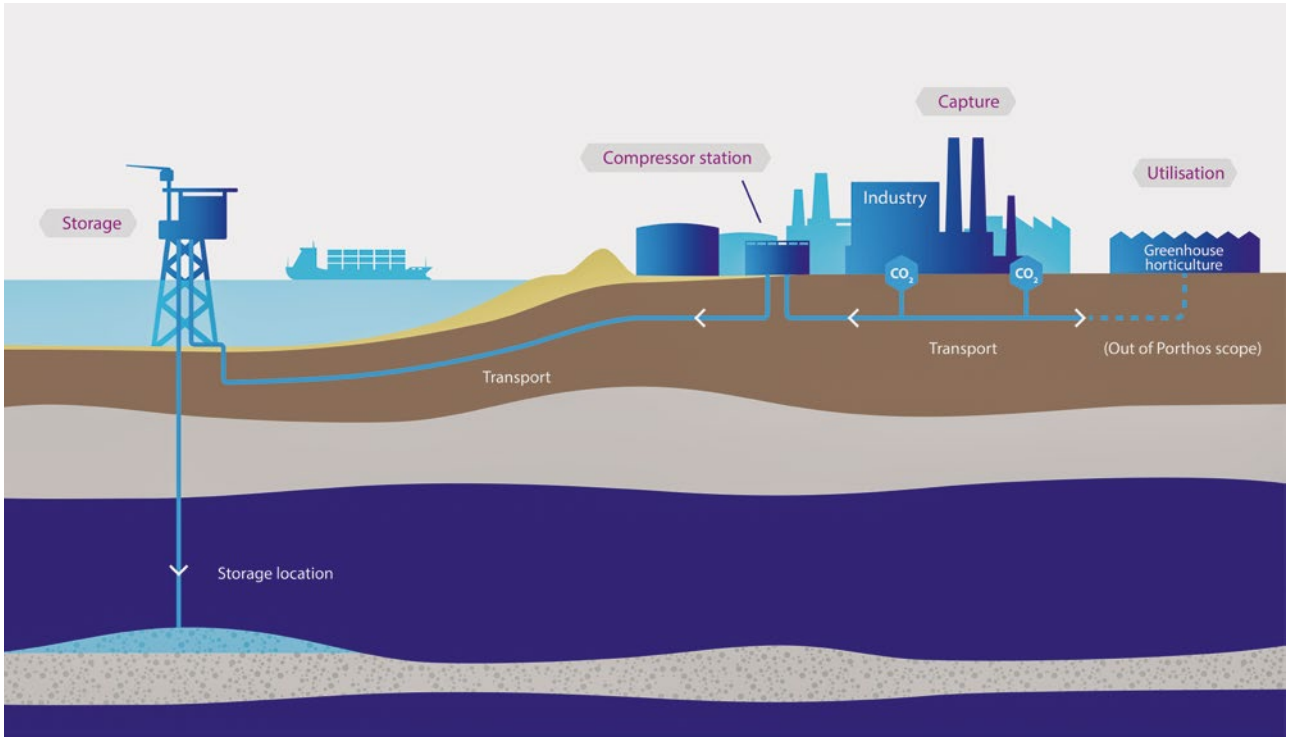
CCUS in the Cement Industry: A Pioneering Project in Brevik

In Brevik, Norway, the world's first large-scale CO_2 capture system is being implemented at a cement plant. This project aims to capture, compress, and liquefy 400,000 tons of CO_2 annually – representing 50 per cent of the plant's emissions. The compressed CO_2 will be transported by ship to an onshore terminal on Norway's west coast, then pumped through a pipeline and stored permanently beneath the North Sea seabed. This project is an essential step in mitigating climate change by storing CO_2 in geological sinks, helping curb global warming.

A key innovation in this CCUS process is the newly developed Carbon Capture Heat Recovery (CCHR) technology, which will be deployed for the first time in Brevik. This system recovers the heat generated during CO_2 compression through a new process, converting it into steam. This steam covers approximately one-third of the energy needs for the CO_2 capture system, reducing energy consumption by 30 per cent compared to conventional carbon capture technologies. The compressor system used for this project was developed and manufactured by MAN Energy Solutions in Germany.

Unlocking Global Potential: Geologically Safe CO_2 Injection and Synthetic Fuels

Injecting CO_2 into depleted gas fields offers a geologically stable solution for CO_2 storage. For example, in Rotterdam, a beacon project named "Porthos" is underway to capture, compress,



Source: Porthos

In the Porthos project, approximately 2.5 MTPA of CO_2 will be stored beneath the North Sea annually.

and transport 2.5 MTPA of CO_2 annually from the industrial port. Over a 15-year period, this CO_2 will be pumped into a depleted gas field located 3,000 meters below the North Sea floor, helping to stabilize the field.

Source: MAN Energy Solutions

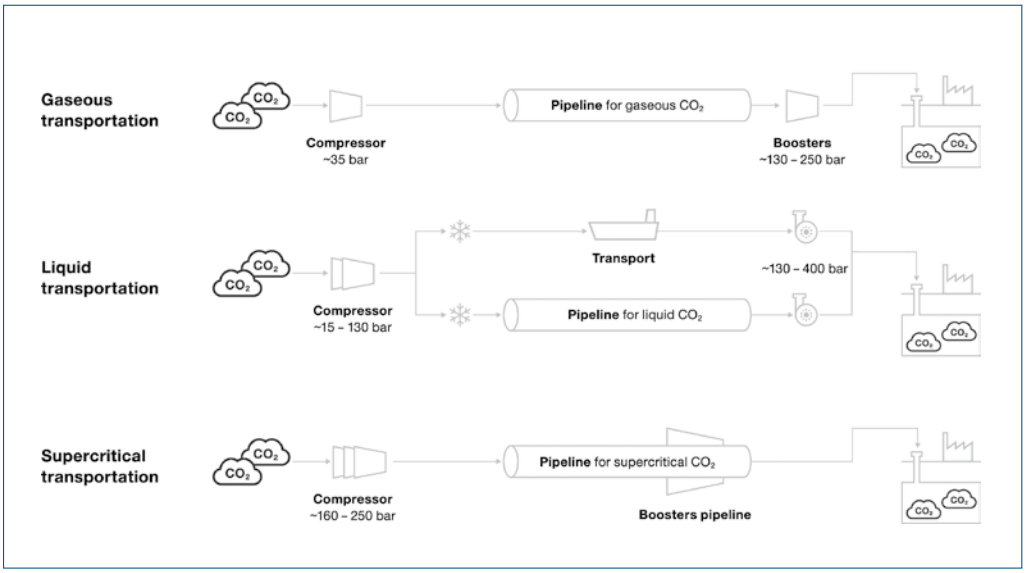
Integrally-geared compressors operate with flow rates of up to 600,000 m³/h and pressures up to 250 bar.

Beyond storage, industrial carbon dioxide can be reused in various processes, such as producing synthetic fuels for combustion engines. In locations where green hydrogen is produced through renewable energy, CO_2 can be utilized to create the C-H chains required for combustion fuels. Ammonia, methanol, and synthetic diesel are already being used to decarbonize the global shipping fleet. Collaboration between engine developers and carbon dioxide utilization experts will continue to be crucial in driving the success of these solutions.

Compressor systems indispensable for sustainable CCUS solutions

Emerging market segments for CCUS, including CO_2 capture, compression, utilization, transport, and storage, are set to grow rapidly. Sophisticated compressor systems are central to the development of these new value chains. With the legally binding "Paris Agreement" and its implementation rules from COP26 in 2021.

Nations are required to submit more ambitious climate action plans every five years. For manufacturers of integrated compressor systems,



Source: Whitepaper „Modular MAN CCUS" / MAN Energy Solutions

The graphic illustrates three CO_2 distribution pathways for reuse and geological storage.

pumps, and motors, the conversion of carbon dioxide into market-ready products, combined with the need for new, cross-border infrastructure, offers excellent growth opportunities.

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With the airjet weaving machines, threads are propelled from one selvedge to another using targeted air currents.

Source: Delcotex

Saving energy with turbo compressors

Sandra Jürging and Lina Sophie Schmidt

Saving resources and energy – those are two aspects that users don't usually associate directly with the operation of compressors that generate oil-free compressed air. But with a new generation of turbo technology, using high-speed motors and an innovative drive concept, these exact results can be achieved. This is what a manufacturer of technical textiles from Bielefeld experienced, too. The company replaced its screw compressors with turbo compressors, thus saving up to 35 per cent energy.

Increasing energy efficiency is currently an important subject, in particular in connection with the use of compressors. After all, compressed air is expensive. It's one of the most frequently used types of energy in the industry, utilised in many areas. Compressed air is not just used to power tools and machines but also to transport materials or for cleaning.

In order to make use as sustainable as possible as well as energy-efficient and therefore cost-efficient, the focus of using compressors should not just be on reducing leaks and using the generated waste heat most effectively. High-quality, state-of-the-art compressor technology with an intelligent control is just as important.

Weaving high-tech textiles with turbo compressors

Turbo compressors are very efficient and can be adjusted easily. They're compact and respond quickly. They're also very reliable and don't incur high servicing costs because their wear is low compared with oil-free screw compressors. That is why the textile manufacturer Delcotex chose turbo compressors provided by BOGE, replacing its oil-free screw compressors that were being used up to this point. At their Bielefeld production site, more than 100 weaving machines, a wide range of special equipment for primary products and systems for quality control are being used in a production area of more than 25,000 m². However, the capacities are no longer sufficient. The Bielefeld company has noticed for a while that the demand for functional textiles is increasing – this includes conveyor belts in airports, roof coverings in supermarkets, parachutes and bullet-proof vests.

In order to expand capacities, the company set up an additional hall three years ago where further textiles are produced and stored. The central part of this production line consists of airjet weaving machines that make fabrics according to specific customer requirements using complex technology. In these machines, threads are propelled from one selvedge to another using targeted air currents. "Thanks to our airjet weaving machines, we can even process very fine yarn quite quickly", explains Lutz Burghoff, Operations and Technology Division Manager, Delcotex. "We can get more than 1,000 weft insertions per minute in this way."

The new turbocompressor series dispenses oil and lubricants.

Various versions for different areas of application

Initially, the company used oil-free screw compressors with an output of 500 kW. Instead of subjecting these machines to an expensive general overhaul, the textile manufacturer invested in new turbo compressors to reduce operating costs in the long term and to increase energy efficiency. The chosen turbo compressors are part of a series that is divided into low-pressure and high-pressure versions. While the low-pressure compressor generates oil-free

Typical areas of application

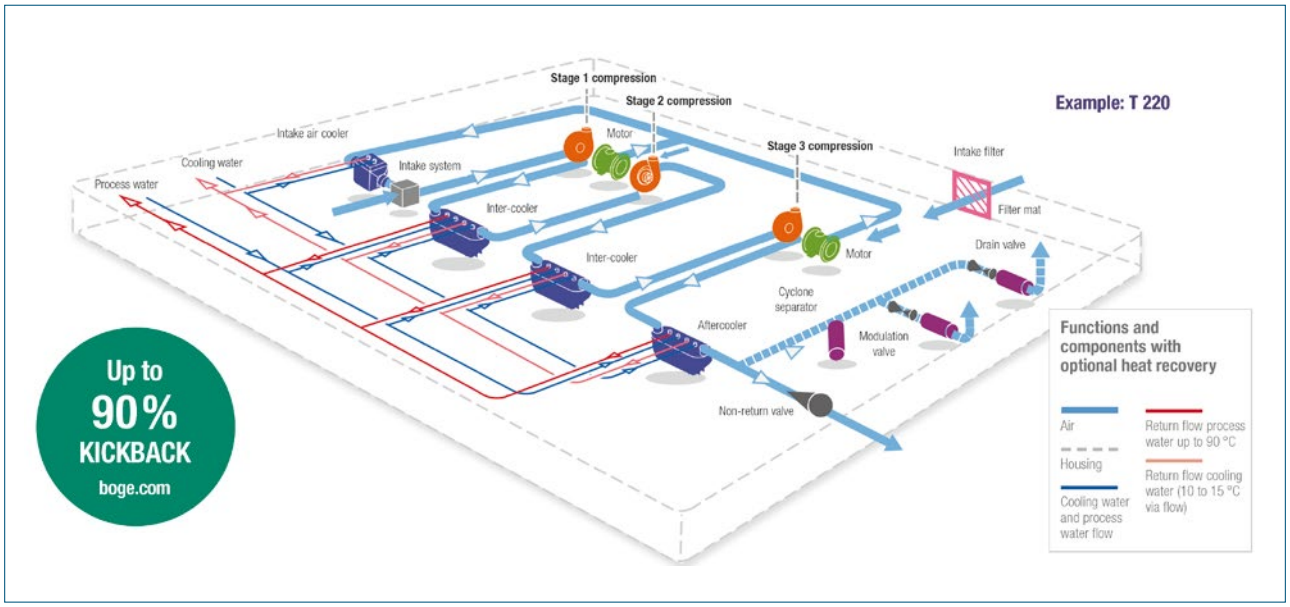
Low-pressure compressor

- Water and waste water treatment
- Metal processing/production lines
- Plastics and chemicals industry
- Glass manufacturing

High-pressure compressor

- Beverages and food industry
- Pharmaceutical industry
- Automotive industry
- Electronics industry

Source: Boge



Source: Boge

All compressors can save 90 per cent energy when heat recovery is used.

compressed air between two and four $bar_{ü}$, the turbo compressor supplies oil-free compressed air between five and eight $bar_{ü}$ with a nominal output of 220 kW.

This series does without oil and lubricants. This is a great advantage compared with oil-free screw compressors, for example, which do provide oil-free compression but require an oil circuit to lubricate the gears and roller bearings. By producing Class 0 oil-free compressed air, turbo compressors are not only suitable for use in the textile industry but also for other sensitive applications.

Fewer components – fewer resources used

The specific power consumption of turbo compressors is significantly lower than that of conventional screw compressors. The design is based on reducing components, thus saving

Source: Delcotex

Delcotex uses more than 100 weaving machines and numerous special systems in Bielefeld.

resources. The core of the design is a drive concept with high-speed motors, multi-stage compression and air-cushioned drive shafts that stabilise themselves. The latter therefore require neither additional energy nor lubricants. This means compressor operation is not just reliable but also low-wear and low-maintenance.

Furthermore, the series features multi-stage compression. Distribution to two airends in the low-pressure compressor and three airends in the high-pressure compressor lowers compression temperatures and reduces mechanical loss. The output temperature of the compressed air is therefore 3 K above the cooling water temperature. The temperatures can be kept below 200 degrees C after each compression stage. Thanks to integrated three-level frequency converters, users can continuously adapt the volumetric flow rate to the relevant requirement. In addition, the frequency converter's multi-level pulse width modulation reduces rotor loss, thus allowing lower rotor temperatures. This means thermal loads can also be reduced. In the same way, the turbo compressor's titanium impellers help to increase efficiency. Speeds of more than 100,000 rpm can be achieved that are maintained during the system's entire full load operation. Additionally, the compressors from this series are half the size of comparable screw compressors and therefore weigh significantly less. Thanks to the compact design, the turbo compressors are also suitable in areas with limited space.

Cooling concept with quiet operation

Practically 100 per cent of air taken in by the compressor is compressed. During this process, it initially passes the intake filter and is partly used to cool the motors. The rest is transported directly to the first airend by an intake receiver. The air warmed by cooling the motors is cooled again and then also used for compression. There is a compressed air cooler downstream of each airend. It guarantees the ideal compressed air inlet temperature for the next airend and minimises the compressed air outlet temperature at the outlet of the compressor. Conversely, the cooling air in screw compressors is guided into the compressor space where it warms up and then needs to be extracted without being used.

Source: Delcotex

By replacing its compressors, Delcotex is saving up to 35 per cent energy.

The noise level of this series is very low. Oil-free screw compressors generate sound pressure levels of 80 dB(A) during use, while low-pressure compressors remain below this value at 73 dB(A) and high-pressure compressors at 70 dB(A). Noise protection measures at the installation site are therefore not required.

Increasing efficiency by using heat recovery

Further energy efficiency increases are possible when the user equips the compressors with a heat recovery system designed for them. This means the primary energy requirement can be minimised because up to 90 per cent of the energy used can be recovered and used for other purposes. No additional space is needed for the integration of heat recovery into the models of this series. The heat from the compressed air process is emitted to the process water. External energy sources are not required. The water reaches temperatures of up to 90 °C and is available for further use, to heat offices, for example. This increases efficiency and minimises the CO_2 footprint. The Bielefeld textile manufacturer plans to use these additional energy savings from heat recovery in the future. “Even if we’re not using this option yet, the turbo compressors provide all the requirements for the comprehensive use of heat”, reports Lutz Burghoff. “That’s a huge advantage because we don’t have to make design changes when we want to start using heat recovery.”

The three turbo compressors used cover a compressed air demand of 90 m³/min at a pressure of 7.6 bar in three-shift operations. Furthermore, the company from Bielefeld benefits from the interlocking control provided by the compressor manufacturer. It can be used to control and manage an unlimited number of compressors, compressed air networks and accessory components – pro-actively and based on demand. “The compressors are always working in accordance with their performance curve”, Lutz Burghoff explains. “We can adapt the generation of compressed air as needed if a machine needs to be converted and is therefore out of service.”

Maintenance concept focusing on sustainability

The compressor series has been designed for a long service life that exceeds that of oil-free screw compressors available on the market. Wear is minimal because neither gears nor fan

motor, neither oil pump nor lubrication systems are installed. The comprehensive maintenance concept also offers planning reliability. If a unit needs to be overhauled, it undergoes a cyclical process. The entire unit is then upgraded. If replacement is required, customers will receive a new or as-new motor or compressor unit and can reduce their CO_2 footprint.

In order to continuously keep its CO_2 footprint low, the Bielefeld textile expert plans to use additional models to absorb production peaks more effectively.

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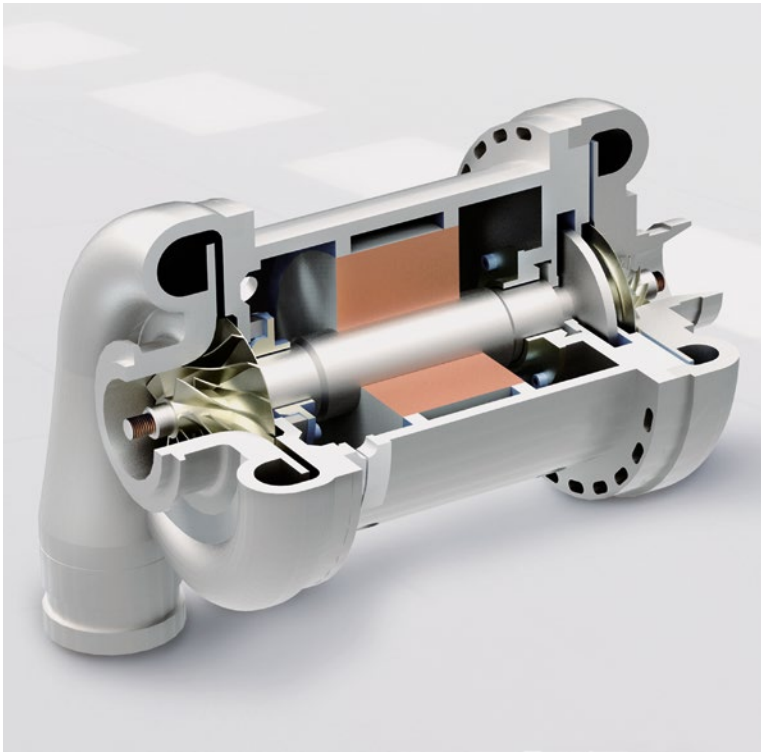


Source: Boge

The drive shafts are air-cushioned and stabilise themselves. They need neither additional energy nor lubrication.

Employees can change cartridges easily and cleanly. Source: Beko Technologies

New condensate treatment system increases efficiency and safety

Norbert Strack

Oil-water separation systems are widely used in industry. These can be used to treat the oily condensate that is inevitably produced during compressed air generation on site, in an environmentally friendly, cost-effective manner and in accordance with legal requirements. However, the operation and handling of such systems pose challenges that can have an impact on efficiency and safety. A newly developed technology now offers major handling and hygiene benefits for oil-water separation. The technology can also be modularly adapted to changing requirements.

Conventional oil-water separators work according to the simple principle of gravity separation. The condensate flows under pressure into a large tank with several filtration stages. The treated water can then be disposed of in the wastewater. However, many companies are dissatisfied with the applied equipment because it requires tightly scheduled maintenance intervals with corresponding operating costs. In addition, changing the activated carbon filters involves dirty, strenuous work. Furthermore, process control is inadequate, which is particularly problematic in demanding applications - for example, where the operating parameters of the compressed air system change frequently, or the compressor oil varies. Due to varying production volumes or if the component design is too small, the systems can overflow at any time without a warning message. This problem prompted the Neuss-based equipment manufacturer Beko Technologies to develop a new system. The company, which specializes in the treatment and management of compressed air, set itself the goal of designing a new oil-water separator:

- which reduces maintenance requirements and costs,
- increases safety,
- offers optimum filter performance even for the most difficult operating conditions and
- is IoT-capable.

IoT-enabled system controls filtration with its own algorithm

The developers from Neuss were the first to integrate valve technology and electronics into an oil-water separator in order to turn a simple filter container into an IoT-capable system that uses its own algorithm to control filtration. This increased the complexity of the system and the development effort. However, in a product development process lasting several years, the company pursued a design thinking approach to successfully reconcile market needs with what was technologically feasible. The method is based on the conviction that challenges can be overcome more easily if creative minds from different areas of the company work together. In addition to engineers and service technicians, the company also involved selected customers and their real-life requirements. Prototypes first had to prove themselves in field tests under real conditions. The Neuss-based company quickly received positive feedback, for example from a user in the paper industry, where cellulose fibers and glues make condensate treatment a particular challenge.

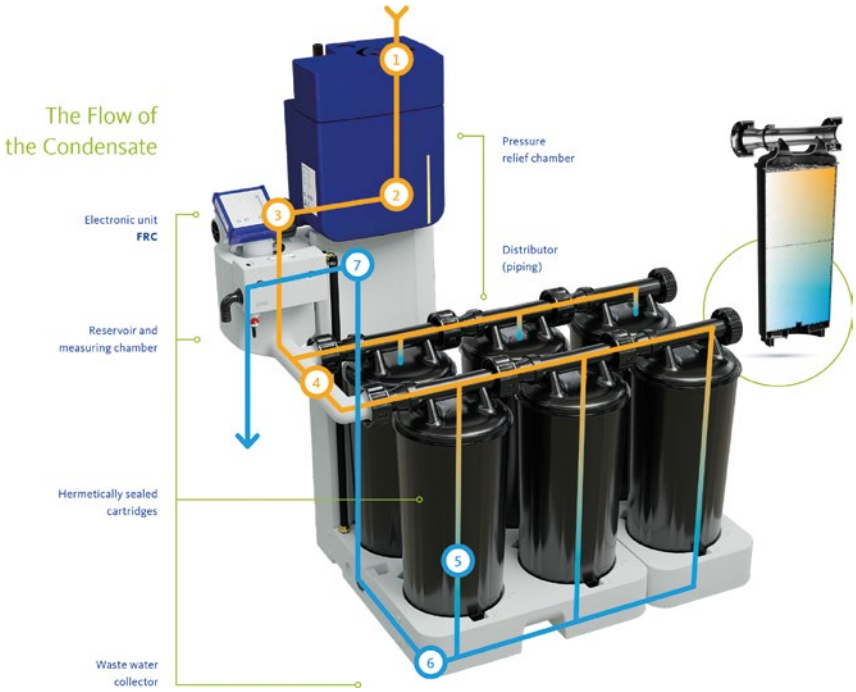
The integrated electronic FRC control makes the oil-water separator IoT capable.

Active separators utilise electrical energy and small amounts of compressed air

The newly developed oil-water separator has an electronic control unit, the so-called Flow Regulation Controller (FRC), as well as filter cartridges in which the actual oil-water separation takes place. As an active system, the device uses electrical energy and small amounts of compressed air for its operation, unlike static separators. The oil-containing condensate first enters a pressure relief chamber. From here, it flows into the valve unit with diaphragm technology and integrated FRC electronic unit. As soon as the sensors detect a defined fill level, the valve closes. The condensate is then pressed evenly into the cartridges via distributor pipes with gentle, automatically triggered bursts of compressed air, instead of just seeping through. The pre-filter and main filter reliably absorb the oil contained in the condensate and bind it

Source: Beko Technologies

The condensate residues are pushed from the piping system into the cartridges using small bursts of compressed air.



Source: Beko Technologies

The flow diagram visualizes the path of the condensate through the oil-water separator.

in the filter material. The cleaned condensate then flows out via the integrated bottom valves and reaches a clean water tank for discharge via a rising channel.

Users not only benefit from a controlled flow rate but can also see how much condensate is flowing through the oil-water separator. In addition, a method of pressurizing the filter cartridges ensures a particularly high and reliable filter performance. All components, such as plastic injection-molded and extruded parts, withstand the pressure difference even under changing environmental conditions. The cartridges are always filled with condensate. This prevents the formation of dry boundary layers and the formation of organic cultures, even during longer breaks in operation.

In addition, the integrated electronic FRC control makes the oil-water separator IoT-capable and displays the remaining capacity of the cartridges as well as status information, such as when service is due. The operating status and any alarm notifications can also be called up permanently via Modbus. This allows the system to be easily integrated into higher-level monitoring and control systems. Users can then view, save and evaluate the data from anywhere. The oil-water separator thus ensures maximum process and functional reliability. The active process also allows the volume of the cartridges to be fully utilized and makes it easier to plan service calls. In the event of a power failure, a fail-safe mode ensures that the device switches to conventional gravity separation and continues to work reliably.

Simple, clean and quick cartridge change

When developing the oil-water separator, Beko Technologies paid particular attention to convenient and clean operability. Once the filters of a cartridge are saturated, the service mode can be started via the control unit. Condensate still contained in the cartridge is then pressed through the filter material using compressed air. The subsequent cartridge change is simple, convenient and can be carried out without tools. To do this, the bayonet fitting of the cartridge is loosened and the cartridge, which only weighs a maximum of 25 kg when saturated, is lifted out of the flat base plate with a twisting motion, with the inlet pipe acting as a stable handle. The user can then close the inlet with blind plugs. The new cartridge is just as easy to insert, and the entire, ergonomically designed process only takes a few minutes.

Changing the cartridge is also extremely hygienic. Unlike with conventional oil-water separators, employees and the working environment cannot encounter the contaminated contents. The oily substances filtered out are hermetically sealed in the cartridge. Any remaining compressed air condensate cannot escape at any time. This eliminates risks for employees and the time-consuming cleaning work that is commonplace in many companies.

Modularly adaptable to requirements

Conventional oil-water separators are designed for a certain amount of condensate. If the capacity is exceeded, for example due to a newly installed, more powerful compressor and the resulting increase in condensate vol-

ume, a new device must be installed. The newly developed oil-water separator, on the other hand, grows with the requirements. The system consists of a base unit and a variable number of filter cartridges. Installation is very quick. It usually takes a maximum of half an hour. By adding or removing base plates and cartridges, the device can be adapted to higher or lower requirements in just a few simple steps. The modular principle makes it easier for companies to make investment decisions and enables safety reserves to be created and service intervals to be customized.

The new oil-water separator is available in five versions, covering compressor capacities from 10 m³/min up to 90 m³/min and thus offering more power than conventional appliances. Due to the active mode of operation, only the compressor capacity and the climate zone at the installation site are criteria for selecting the

Source: Beko Technologies

The electronic control unit makes the system IoT-capable and displays status information.

Source: Beko Technologies

Condensate samples are analyzed in the laboratory to provide precise recommendations for the appropriate separation system.

right appliance. The type of compressor and the compressor oil used, on the other hand, are not relevant for the design. Users have a major advantage with the cartridges - one size fits all. Companies can use one cartridge for every model. The standard size also makes procurement and stocking easier for users and service technicians.

The oil-water separator can be easily integrated into existing operating environments.

The oil-water separator can be easily integrated into existing operating environments and requires very little space. Thanks to the approval of the German Institute for Building Technology (DIBt), the system is ready for immediate connection, meaning that no complex approval procedures or water law permits are required. A separate sampling valve enables regular visual turbidity checks of the treated condensate without interrupting operation.

Longer maintenance intervals – more cleanliness

A customer from the automation and connection technology sector has been using the new oil-water separator for a year and a half and reports longer maintenance intervals. The fact that the filter now only needs to be changed once a year - instead of up to four times a year - is a significant improvement on the multiple filter changes required by the previous system and helps to reduce operating costs. Maintenance staff also appreciate the cleanliness of the system. The device also proves its reliability in the summer months, when high temperatures and humidity cause more compressed air condensate to accumulate. The company has therefore already ordered further treatment systems for other production sites - a major step forward in industrial wastewater treatment.

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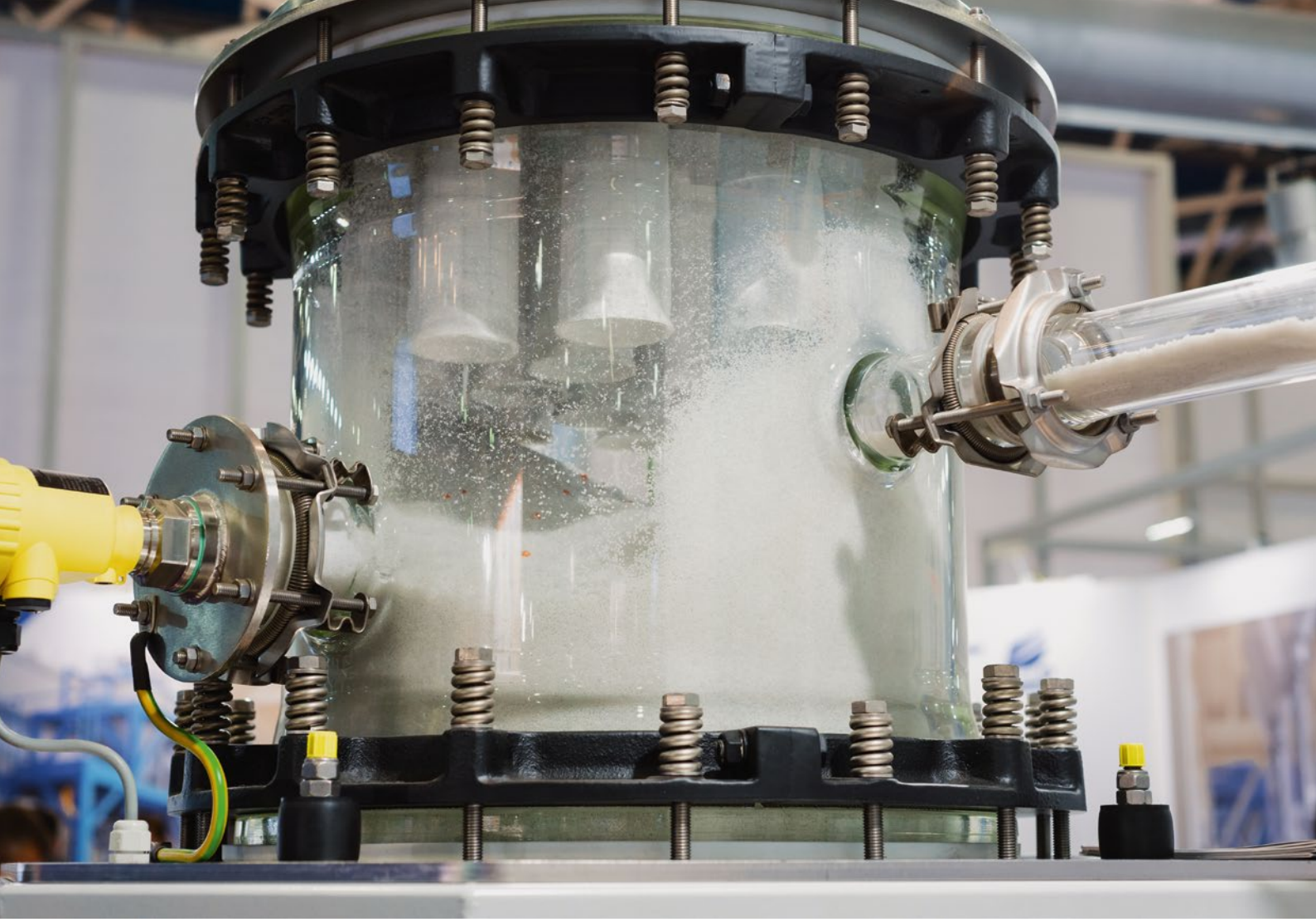


The new High Speed Radial Blower is suitable for the beverage industry. Source: Shutterstock.com

High Speed Radial Blower increases efficiency

Kristof Suykerbuyk and Markus Kopf

The High Speed Radial Blower is establishing itself as a solution that brings sustainability and operational efficiency together. This technology enables energy savings of up to 60 percent compared to traditional blower technologies and supports central Industry 4.0 concepts such as predictive maintenance and real-time monitoring. This blower was developed through close cooperation between research and industry and creates the foundation for a more sustainable process & manufacturing environment.

Possible Applications for the High-Speed Radial Blower

- **Pneumatic Conveying Systems:** The compressor enables consistent airflow for the efficient transport of granules and powders, particularly in automation technology. The precisely adjustable air supply and high energy efficiency make it ideal for continuous operation.
- **Food and Beverage Industry:** Here, oil-free operation provides a clean solution to avoid contamination, such as might be needed for packaging and vacuum sealing. Its compact design facilitates integration into existing systems.
- **Hydrogen Fuel Cells:** In the field of renewable energies, the High Speed Radial Blower plays an important role by providing the airflow needed for the operation of fuel cells. Its flexibility ensures that fuel cells can operate efficiently under various load conditions.

The adaptability and flexibility of the blower are especially important in industries with fluctuating air demand, such as the textile and printing industries.

Source: Elmo Rietschle

In a world where sustainability and operational efficiency are increasingly shaping the industrial landscape, the High Speed Radial Blower marks a milestone in manufacturing technology. The blower was developed to meet the increasing demand for more environmentally friendly manufacturing processes. It unites the imperatives of energy saving with the high performance required by today's applications.

The adaptability and flexibility of the blower are particularly important in industries with fluctuating air demand, such as the textile and printing industries.

Integration in Industry 4.0 Environments

Facing increasing environmental regulations and pressure to reduce energy consumption, companies must find solutions that reconcile their operational efficiency with ecological responsibility. European legislation plays a key role in this: The EU directive to reduce energy consumption by 11.7 percent by 2030, the mandates to minimize water consumption, and the regulation (EU) 2021/1119 to cut greenhouse gas emissions by 55 percent by 2030 set clear frameworks for the development and implementation of such technologies.

The High Speed Radial Blower is designed for the demands of Industry 4.0 and is compatible with key technologies such as the Internet of Things (IoT), artificial intelligence (AI), and machine learning. Its integration not only enhances productivity but also enables predictive maintenance and real-time monitoring. These technologies contribute to optimizing maintenance intervals and minimizing disruptions, which extends operating time and lowers energy consumption.

Operational Agility and Cost Management

In today's competitive market, operational flexibility is as crucial as effective cost management. The High Speed Radial Blower allows companies to quickly adapt to changing requirements while keeping operating costs low. With energy savings of up to 60 percent compared to conventional technologies, such as side-channel technologies often employed in these pressure ranges, this blower offers an economical and eco-friendly solution. The High Speed Radial Blower achieves an isentropic efficiency of 87 percent, which sets it apart from traditional technologies that typically achieve 75 percent. With this efficiency, the blower significantly exceeds the efficiency requirements for radial blowers from the ErP Directive 327/2011.

The blower's speed can be controlled using built-in or external frequency converters, allowing for optimal operating point adjustment. Depending on the size, the blowers can operate in a speed range of 10,000 to 22,000 rpm. The technology combines oil-free operation, eliminating the risk of contamination, with reduced maintenance and a compact design, making the blower versatile and ideal for applications that demand high energy efficiency and minimal maintenance effort.

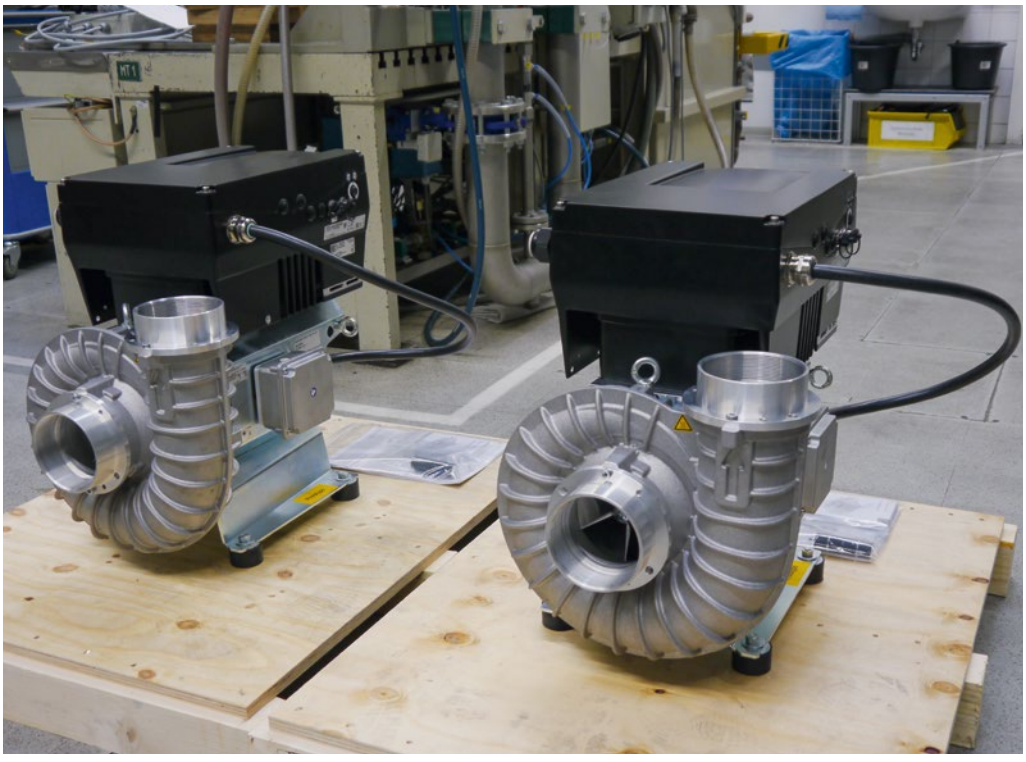
Technology in Detail:

- **Optimized Aerodynamics:**
  The manufacturer has shaped the geometry of the impeller and volute to guide airflow through the blower with minimal losses. Flow simulations were used to optimize efficiency and minimize noise sources and flow detachments. The calculated results were verified through trials. The measured sound pressure level according to EN ISO 3744, measured at a 1-meter distance and with connected ducts, does not exceed 80dB(A) even at maximum speeds of over 22,000 rpm.
- **Powerful Synchronous Motor:**
  The permanent magnet synchronous motor used is efficient even at high speeds. These motors are more efficient under variable load conditions than conventional asynchronous motors, thereby contributing significantly to energy savings. Mechanical losses have been minimized with the use of hybrid bearings with low friction losses.

The use of hybrid ball bearings with low friction losses reduces mechanical losses in the drive system.

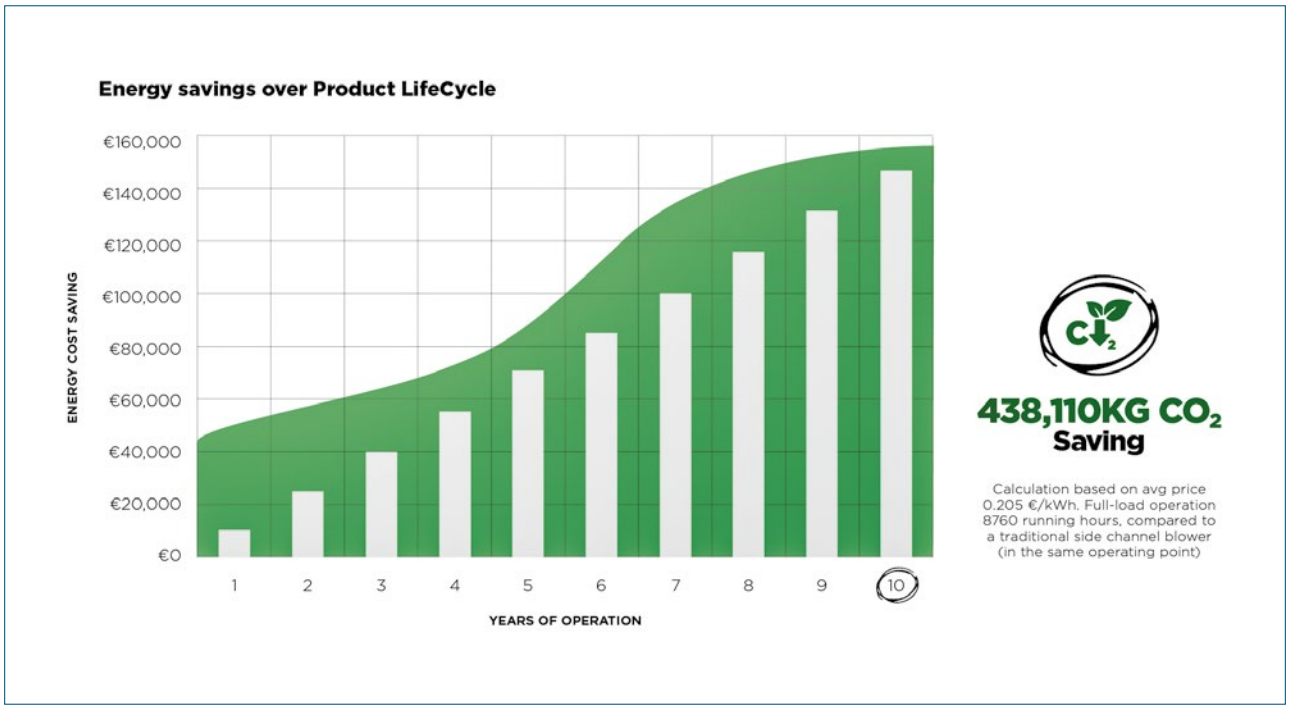
Intensive Research and Cooperation with Industry

An experienced team of engineers has advanced the development of the High Speed Radial Blower, working to improve every aspect of the system. Through close cooperation with selected customers, a blower was developed that fulfills the necessary industry and application requirements.



Source: Elmo Rietschle

The High Speed Radial Blower combines sustainability and operational efficiency.



Source: Elmo Rietschle

The High Speed Radial Blower saves up to 60 percent of energy compared to conventional side channel blowers.

The efficient blower is suitable for a wide range of vacuum and pressure applications, especially where many operating hours per year are necessary. Significant amounts of energy and CO_2 emissions can be saved here. Typical applications include pneumatic conveying systems, packaging in the food and beverage industry, as well as air supply for fuel cells.

A Look into Practice

The performance curve of the High Speed Radial Blower shows a broad operational range. In one case study, which required 1,750 m³/h of air at a pressure differential of 100 mbar(g), the blower achieved significant energy savings (97.6 MWh per year) compared to a conventional side-channel blower. This reduces the operating costs by tens of thousands of euros per year depending on the price of electricity and saves a total of 33.6 tons of CO_2 per year.

The High Speed Radial Blower combines technological advancement and sustainability in blower technology – two aspects that are increasingly gaining in importance. With its high savings compared to conventional technologies, the blower makes a significant contribution to reducing the ecological footprint in the manufacturing industry. Compact construction opens up new possibilities for original equipment manufacturers and end-users who can now improve their systems without space constraints.

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Customers train in leak detection at the manufacturer.

Source: Pfeiffer Vacuum+Fab Solutions

Leak testing for safe and efficient cooling and refrigeration circuits

Pfeiffer Vacuum+Fab Solutions

The European F-gas regulation on fluorinated greenhouse gases and the standard for the leak tightness of circuits that regulate the use of coolants and refrigerants are being tightened. This measure is unsurprising, since the immense potential of refrigerants to generate greenhouse gases is increasingly in the spotlight in the context of global warming. Many manufacturers and users must comply with these regulations. There is also a growing demand for energy-efficient heating, ventilation, air conditioning and cooling systems. Modern leak detection systems help to ensure the tightness of refrigeration and refrigeration circuits and make their operation sustainable.

Source: Shutterstock

Air conditioning systems are also mainstream in the private sector and are subject to the F-gas Regulation as well.

A cold beer from the fridge or a pleasant 20 degrees in the office: People encounter refrigeration and air conditioning every day. While refrigerators cool small spaces, air conditioners keep our homes, offices and supermarkets at a comfortable temperature.

Tracer gas recovery systems are an economical and sustainable solution to reduce tracer gas costs.

This is due to a long-known physical principle: the alternation between gaseous and liquid states of aggregation.

When a liquid becomes a gas, it expands. This draws heat from the environment. In the industrial sector, refrigerants are used for this process. They evaporate or boil at much lower temperatures than water and enable heat to be extracted more quickly from their surroundings. An example of this is air conditioning systems in cars.obility bei Pfeiffer Vacuum+Fab Solutions.

The refrigeration cycle essentially consists of a compressor, evaporator, condenser, expansion valve and various connection points. It also includes welds and bolted connections between the individual components. Each of these components must be leak tested to ensure that the complete refrigeration circuit system (HVAC-R = heating, ventilation, air conditioning and refrigeration) functions efficiently and sustainably throughout its life cycle. “Increasing regulatory requirements for the tightness of refrigerant systems highlight the importance of precise and reliable leak detection to minimize the environmental impact of refrigerants,” says Jonas Klös, Market Manager Mobility at Pfeiffer Vacuum+Fab Solutions.

Minor leak – major damage

The tightness of cooling and refrigeration systems is evaluated based on the refrigerant mass loss and measured in grams per year (g/a). Here, the permissible loss values vary depending on the scope and system size. Compact systems in private homes or small commercial operations typically have lower loss rates. Larger commercial systems, such as in hotels, office buildings or hospitals, are more vulnerable to leaks due to their increased complexity and capacity.

In the industrial sector, where refrigeration systems are used in large-scale processes such as the production of foodstuffs and pharmaceuticals, even stricter refrigerant loss requirements usually apply. These systems are often complex and used intensively, which makes them potentially more prone to loss. To adhere to the requirements dictated by regulations and standards, refrigeration circuits must be kept as leak tight as possible. Even the smallest leaks of 10 µm can cause immense damage, such as:

- Reduced system performance
- Increased energy requirements
- Overheating
- Damage to and failure of the compressor
- Environmental damage due to refrigerant leakage

“With this in mind, the tightness of these systems is crucial for long-term efficient and sustainable performance,” says René Polaczek,

F-gas Regulation – EU No. 2024/573

The aim of the F-gas Regulation is to avoid emissions of fluorinated greenhouse gases. Fluorinated greenhouse gases are, for example, fluorinated hydrocarbons, such as tetrafluoromethane (CF4), partially fluorinated hydrocarbons such as trifluoromethane (CHF3), and sulphur hexafluoride (SF6). These are used as refrigerants in air conditioning or refrigeration systems. The total amount of permitted refrigerant is not stated in kilograms, but in tons of CO_2 equivalent. 1 kg CO_2 = 1 kg CO_2 equivalent.

Source: Pfeiffer Vacuum+Fab Solutions

Market Manager Mobility at Pfeiffer Vacuum+Fab Solutions. "Because the consequences of leaks are downtime and higher operating costs for refrigerants, service or electricity – to name just a few aspects."

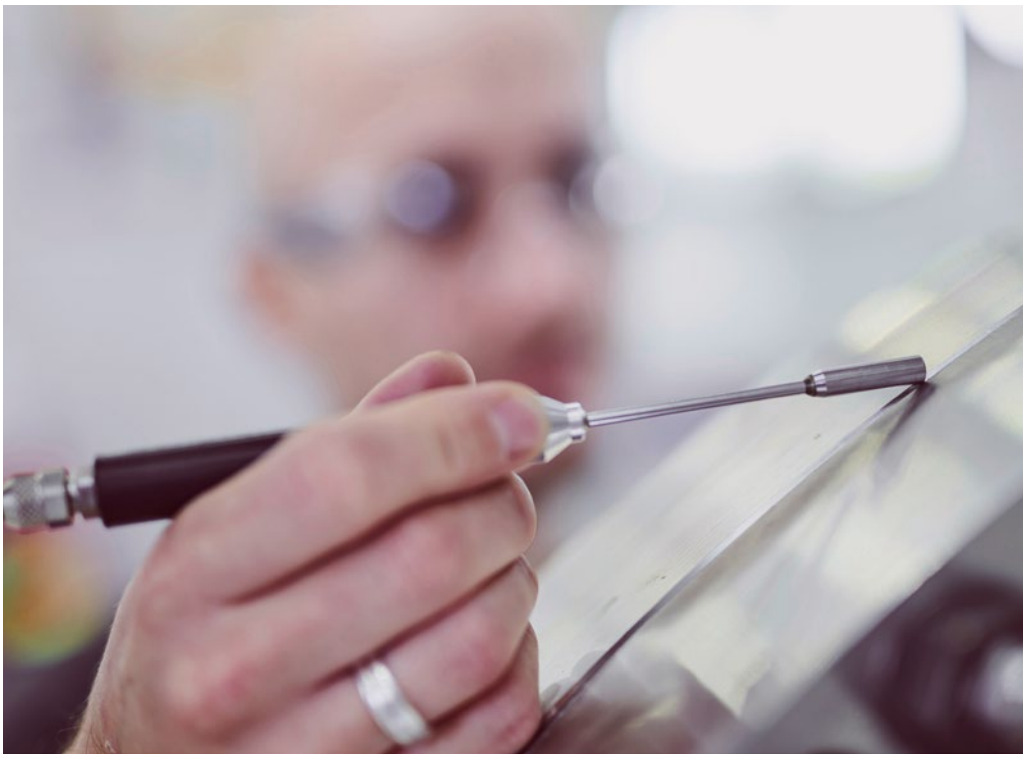
System adjustments required

The increasingly strict regulations and standards present the industry with ever greater challenges. The Kigali Amendment applies at the international level. In Europe, the European F-gas Regulation – 573/2014/EU applies.

As a result, various refrigerants with high global warming potential (GWP) will be phased out by 2030. This involves a lot of effort for suppliers and manufacturers to redesign their system so that it can be fitted with a different refrigerant and continue to work efficiently and cost-effectively.

Detect leaks early

Improved, more energy-efficient HVAC-R systems are required to meet the regulations. In addition, the demand for more stringent qual-



Source: Pfeiffer Vacuum+Fab Solutions

The purpose of the sniffing test is to locate leaks.

ity and productivity standards is growing, so leakage control already plays an important role in the production process for both manufacturers and users. The main point here is that the drying and leak testing of the systems in use have a direct effect on the service life and performance of the equipment. To ensure that leaks can be detected and repaired at an early stage, all components that come into contact with refrigerant are usually tested individually during manufacturing.

The tracer gas leak detector covers all industrial sniffing applications.

The requirements for the leak test process are varied and take into account factors such as the tracer gas used, its concentration and the leak rate limit (value between “leak-tight” and “leaking”). In addition, the test time and the degree of automation play a decisive role. Furthermore, it is important to consider whether this is being done to locate a leak or to measure quantified leak rates. In order to comply with the required leak rate limit, a leak test is carried out under vacuum or an accumulation chamber after a gross leak test (for example, using air-based test methods). A sniffing test can also help to locate a leak. Once the individual components have been successfully tested, the next production step is to assemble them into a system and weld them together. After an optional gross leak test with air, the refrigeration circuit is simultaneously evacuated and vacuum-dried.

Increased longevity thanks to vacuum drying

The evacuation and simultaneous drying of the system have a major influence on its subsequent efficiency and reliability.

Particular attention is paid to drying the residual moisture: The challenge is removing the thin (naturally occurring) layer of moisture that adheres to the internal surfaces of the compressor, condenser, evaporator, valves and tubing. If the system is not actively dried, residual moisture remains, which can freeze during operation and cause failures in the expansion valve or closing pipe. In addition, water reacts with the refrigerant to form acids that can corrode or form deposits, threatening overall system failure. Vacuum drying is therefore crucial for successful long-term operation of the system. It reduces residual moisture on the internal surfaces of the components and improves both the subsequent leak testing process and the refrigerant filling process.

Typically, oil-lubricated rotary vane vacuum pumps with a pumping speed of 10 to 30 m³/h are used for the leak testing process and during the filling of refrigerant. In addition to oil-lubricated rotary vane vacuum pumps, dry scroll vacuum pumps are also used. In this application, there is a trend towards switching to oil-free solutions as they reduce maintenance effort and save on oil costs. At the same time, there is no need to dispose of the used operating fluid.

Once the refrigeration circuit is evacuated and vacuum dried, a tracer gas, such as helium or hydrogen, is introduced. During this process, the test pressure should correspond to the subsequent working pressure of the system so that a leakage test can be carried out under real conditions. To save costs related to the tracer gas, tracer gas concentrations of 100% are often not used. For the tracer gas to be distributed effectively throughout the system, the system must offer optimal conditions. This means an airless space, free of humidity and other gases. Tracer gas recovery systems are ideal for systems with a large refrigeration circuit volume.

Sniffing leak detector for reliable leak detection

A sniffing leak detector from Pfeiffer Vacuum+Fab Solutions is used to test the individual welded and soldered joints, as well as the valves and connections. Leak tests with helium or hydrogen sniffing leak detectors are far superior in terms of response time, accuracy and sensitivity to conventional leak detection methods, such as the water bath method or the pressure rise test. The helium and hydrogen sniffing leak detector is designed for 24-hour use, even in harsh environments. With its high

Source: Shutterstock

The F-gas Regulation will apply to existing heat pumps from January 2026.

sensitivity of 0.2 g/a, it enables precise and error-free measurements that meet the stringent requirements of air conditioning and refrigeration applications. Designed to perform fast and repeatable measurements, this instrument offers short recovery times, even in the event of large leaks, ensuring maximum operational availability coupled with low maintenance costs. Users benefit from longer maintenance intervals and easier replacement of wearing parts.

But the sniffing leak detector is not only convincing in terms of its accuracy and economic efficiency. Ease of use and intuitive operation support efficient working thanks to the lightweight, ergonomically molded sniffer probe that ensures simple measurements and precise results even from a greater working distance. At the same time, it ensures comfort while working. The high-resolution 7" touchscreen is easy to use. Colorful LEDs light up on the sniffer probe depending on the strength of the signal and ensure error-free readability in real time. The sniffer probe is available in different hose lengths. Depending on the application, replacement is possible at any time. The compact design and low space requirements also make it easy to integrate in the production line.

The tracer gas leak detector covers all industrial sniffing applications and has particularly proven itself in leak testing of refrigeration and air conditioning units.

The robust construction ensures low maintenance and operating costs with reliable use around the clock.

Author:
Pfeiffer Vacuum+Fab Solutions
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Applications Process & Compressed Air Technology

	Products				Fields of application																						
	Compressed air generation	**Compressed air treatment**	**Compressed air distribution**	**Process compressors**	**Hygiene**	Breweries	Medical technology	Food industry	Packaging (except Food)	Laboratory	Cleaning (Purging)	**Oil/Gas**	Natural gas industry	Oil fields	Petrochemical industry	Refineries	Biogas	Gas stations (natural gas, LPG)	**Handicrafts/Workshops**	Workshops	Handicrafts	Garages	**Pneumatic**	Mechanical engineering	Switchgear	
ABN Apparatebau Nittenau GmbH www.abn-drucklufttechnik.de						●	●	●	●	●	●						●			●	●			●		
Aerzener Maschinenfabrik GmbH www.aerzen.com				●		●		●	●		●		●	●	●	●	●			●				●	●	
ALMiG Kompressoren GmbH www.almig.de	●	●				●	●	●	●	●	●		●	●	●	●	●			●	●	●		●	●	
Apex Tool Group GmbH & Co. OHG www.apexpowertools.eu			●																	●	●	●		●	●	
Atlas Copco Energas GmbH, Gas and Process Division www.atlascopco-gap.com				●		●		●					●	●	●	●	●	●								
Atlas Copco Kompressoren und Drucklufttechnik GmbH www.atlascopco.de	●	●	●			●	●	●	●	●	●		●	●	●	●	●	●		●	●	●		●	●	
Gebr. Becker GmbH www.becker-international.com	●					●	●	●	●	●	●													●		
J. A. Becker & Söhne GmbH & Co. KG www.jab-becker.de	●	●		●				●	●	●	●		●	●	●	●	●	●						●	●	
BEKO TECHNOLOGIES GmbH www.beko-technologies.de		●				●	●	●	●	●	●		●		●	●	●	●		●	●	●		●	●	
BlitzRotary GmbH www.blitzrotary.com	●	●																		●	●	●		●		
BOGE KOMPRESSOREN Otto Boge GmbH & Co. KG www.boge.de	●	●	●			●	●	●	●	●	●		●	●	●	●	●	●		●	●	●		●	●	
ITT Bornemann GmbH www.bornemann.com						●		●					●	●	●	●	●									
BORSIG ZM Compression GmbH www.borsig.de/zm				●									●	●	●	●	●									
M. Braun Inertgas-Systeme GmbH www.mbraun.de										●																
Dr.-Ing. K. Busch GmbH www.buschvacuum.com/de/de/				●		●	●	●	●	●	●			●	●		●			●				●		
Cejn-Product GmbH www.cejn.de			●			●	●		●	●	●		●	●	●	●	●	●		●	●	●		●	●	
CVS engineering GmbH www.cvs-eng.de	●												●		●		●			●	●	●				
Deprag Schulz GmbH & Co. www.deprag.com			●			●	●	●	●	●			●	●	●	●	●	●		●	●			●		
Donaldson Filtration Deutschland GmbH www.donaldson.com		●				●	●	●	●	●	●		●		●	●	●							●	●	
FST GmbH Filtrations-Separations-Technik www.fstweb.de		●				●	●	●	●	●	●		●	●	●	●	●	●		●	●	●		●	●	
Gardner Denver www.gardnerdenver.com	●	●				●	●	●	●	●	●		●	●	●	●	●	●		●	●	●		●	●	
Gardner Denver Deutschland GmbH, CompAir www.compair.com	●	●				●	●	●	●	●	●		●	●	●	●	●	●		●	●	●		●	●	

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																						Chemical industry
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●	●	●		●		●	●				●	●			●	●		●	●	●		Woodworking and processing
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																						Foundries/Wind channels
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																						Paint plants/Sand blasting plants
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●	●	●	●	●	●	●	●			●	●		●	●	●	●		●	●		●	Railway vehicle
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																						Other fields of applications
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		●	●						●					●								**Hydrogen technology**

Applications Process & Compressed Air Technology

	Products				Fields of application																						
	Compressed air generation	**Compressed air treatment**	**Compressed air distribution**	**Process compressors**	**Hygiene**	Breweries	Medical technology	Food industry	Packaging (except Food)	Laboratory	Cleaning (Purging)	**Oil/Gas**	Natural gas industry	Oil fields	Petrochemical industry	Refineries	Biogas	Gas stations (natural gas, LPG)	**Handicrafts/Workshops**	Workshops	Handicrafts	Garages	**Pneumatic**	Mechanical engineering	Switchgear	
Gardner Denver Deutschland GmbH, Elmo Rietschle www.gd-elmorietschle.com	●					●	●	●	●	●	●		●	●	●	●	●	●		●	●	●		●	●	
Gardner Denver Deutschland GmbH, Robuschi www.robuschi.com	●					●	●	●	●	●	●		●	●	●	●	●	●		●	●	●		●	●	
Gardner Denver Deutschland GmbH, Nash www.gdnash.com	●												●	●	●	●	●									
GEA Group Aktiengesellschaft www.gea.com		●				●		●					●		●	●										
HAUG Sauer Kompressoren AG www.haug.ch				●		●	●	●	●	●	●		●	●	●	●	●							●	●	
Ingersoll-Rand GmbH www.ingersollrandproducts.com	●	●	●			●	●	●	●	●	●		●	●	●	●	●			●	●	●		●	●	
KAESER Kompressoren SE www.kaeser.com	●	●	●			●	●	●	●	●	●		●	●	●	●				●	●	●		●	●	
KNF Neuberger GmbH www.knf.com						●	●	●	●	●	●		●	●	●	●	●	●		●	●	●		●	●	
Körting Hannover GmbH www.koerting.de				●		●		●					●		●	●										
MAN Energy Solutions SE www.man-es.com				●									●	●	●	●	●							●		
MANN+HUMMEL GmbH www.mann-hummel.com		●																								
Mattei Kompressoren Deutschland GmbH www.matteigroup.com	●	●				●	●	●	●	●	●		●	●	●	●	●			●	●	●		●	●	
Mehrer Compression GmbH www.mehrer.de				●		●	●	●	●		●		●	●	●	●	●	●						●		
MTA Deutschland GmbH www.mta.de		●				●		●	●								●				●			●		
Neuenhauser Kompressorenbau GmbH www.nk-air.com	●									●	●		●	●	●	●								●		
NEUMAN & ESSER GROUP www.neuman-esser.com				●		●		●		●			●	●	●	●	●	●						●		
Parker Hannifin GmbH www.parker.com		●	●			●	●	●	●	●	●		●	●	●	●	●	●		●	●	●		●	●	
Piab Vakuum GmbH www.piab.com						●	●	●	●	●	●				●									●	●	
ITT Rheinhütte Pumpen www.rheinhuette.de						●		●					●		●	●	●							●		
RKR Gebläse und Verdichter GmbH www.rkr.de	●			●		●	●	●	●	●	●		●	●	●	●	●							●		
MultiAir Germany GmbH www.schneider-airsystems.de	●					●	●	●	●	●	●									●	●	●		●	●	
Siemens-Energy AG www.siemens-energy.com				●									●	●	●	●	●									

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	●	●	●	●	●				●	●			●	●	●	●		●	●	●	●	Textile industry
																						Storage and transport
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		●		●	●										●	●				●	●	Silos
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																						Sewage plants
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																						Foundries/Wind channels
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		●				●						●			●	●			●	●	●	Wind channels
●		●			●	●			●			●			●	●			●	●	●	Blast furnace blowers
●		●							●			●			●	●			●	●	●	Coke oven blowers
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																						Paint plants/Sand blasting plants
	●	●	●	●	●				●	●	●				●	●	●			●	●	Paint plants
	●	●		●	●					●	●				●	●				●	●	Sand blasting plants
																						Vehicles and Navigation
		●		●	●	●	●			●	●				●					●	●	Railway vehicle
		●		●		●				●	●			●						●	●	Road vehicle
		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	Navigation
				●	●		●			●							●			●	●	Starting of engines and power units
																						Other fields of applications
	●	●	●		●				●	●	●	●	●	●	●	●	●	●	●	●	●	Drying
	●				●					●				●	●		●			●	●	Drives
●		●			●			●		●		●			●	●	●			●	●	Heat recovery
●				●		●						●										**Plastic production/processing**
●				●		●			●			●		●			●					**Hydrogen technology**

Applications Process & Compressed Air Technology

	Products				Fields of application																						
	Compressed air generation	**Compressed air treatment**	**Compressed air distribution**	**Process compressors**	**Hygiene**	Breweries	Medical technology	Food industry	Packaging (except Food)	Laboratory	Cleaning (Purging)	**Oil/Gas**	Natural gas industry	Oil fields	Petrochemical industry	Refineries	Biogas	Gas stations (natural gas, LPG)	**Handicrafts/Workshops**	Workshops	Handicrafts	Garages	**Pneumatic**	Mechanical engineering	Switchgear	
SMC Deutschland GmbH www.smc.de		●	●			●	●	●	●	●	●														●	
STASSKOL GmbH www.stasskol.de				●		●	●	●					●	●	●	●	●	●						●		
Ultrafilter GmbH www.ultraair.de / www.ultra-filter.de		●				●	●	●	●	●	●		●		●	●	●	●		●	●	●		●	●	

	Control air	Instrument air	**Chemical industry**	Chemical industry	Fertilizer production	**Construction/Woodworking/Textile**	Construction	Woodworking and processing	Textile industry	**Storage and transport**	Filling systems	Silos	Bulk handling	Pneumatic dispatch blowers	**Sewage plants**	Sewage plants	Aerating	**Foundries/Wind channels**	Foundries	Wind channels	Blast furnace blowers	Coke oven blowers	Oil field blowers	**Paint plants/Sand blasting plants**	Paint plants	Sand blasting plants	**Vehicles and Navigation**	Railway vehicle	Road vehicle	Navigation	Starting of engines and power units	**Other fields of applications**	Drying	Drives	Heat recovery	**Plastic production/processing**	**Hydrogen technology**
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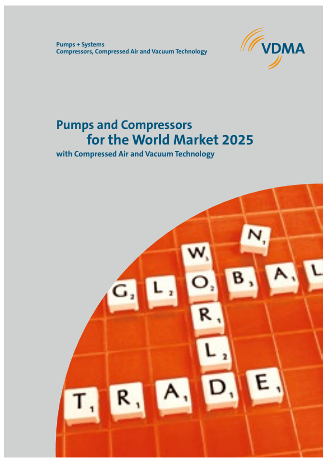

Applications Vacuum Technology

	Rough Vacuum	Packaging (except Food)	Central Vacuum	Printing and Paper Handling	Pick and Place	Conveying	Air sampling	Medical	**Process Vacuum**	Chemical	Petrochemical	Pharmaceutical	Plastics	Food	Beverage	Textile	Paper	Ceramics	Freeze drying	Energy (Wind, Nuclear, Steam turbines, ...)	**Industrial Vacuum**	Vacuum Metallurgy[1]	Vacuum Heat Treatment[2]	Laser Technology	Electron Tubes	TV Tubes	Lamps and Bulbs
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Aerzener Maschinenfabrik GmbH www.aerzener.de		●	●	●	●	●				●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●
Apex Tool Group GmbH & Co. OHG www.apexpowertools.eu				●																							
Atlas Copco Kompressoren und Drucklufttechnik GmbH www.atlascopco.de		●	●	●	●	●	●			●	●	●	●	●	●	●	●	●	●	●		●	●				
Gebr. Becker GmbH www.becker-international.com		●	●	●	●	●	●	●					●	●	●	●	●		●					●			●
ITT Bornemann GmbH www.bornemann.com										●	●		●	●	●												
M. Braun Inertgas-System GmbH www.mbraun.de										●		●												●			●
Dr.-Ing. K. Busch GmbH www.busch.de		●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●
CVS engineering GmbH www.cvs-eng.de						●																					
Flowserve-Sterling SIHI GmbH www.flowserve-sihi.com		●	●	●		●		●		●	●	●	●	●	●	●	●	●	●	●		●	●				●
Gardner Denver www.gardnerdenver.com		●	●	●	●	●	●	●		●	●	●	●	●	●	●		●	●	●		●	●	●	●	●	●
Gardner Denver Deutschland GmbH, Elmo Rietschle www.gd-elmorietschle.com		●	●	●	●	●	●	●		●	●	●	●	●	●	●		●	●	●		●	●	●	●	●	●
Gardner Denver Deutschland GmbH, Robuschi www.robuschi.com		●	●	●	●	●	●		●	●	●	●	●	●		●	●	●		●			●		●	●	
Gardner Denver Deutschland GmbH, Nash www.gdnash.com		●	●			●				●	●	●	●	●	●	●	●	●	●	●		●					
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HERMETIC-Pumpen GmbH www.hermetic-pumpen.com										●	●	●	●														
KAESER Kompressoren SE www.kaeser.com		●	●	●	●	●				●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●

1 (Metal Degassing, Melting, Re-melting, e-beam welding, casting, ...)

2 (Brazing, Carburising, Nitriding, Quenching, ...)

3 for Semiconductor including focused ion beam systems and electron beam systems

●				●	●	●			●						●	Industrial leak detection
		●		●					●			●				Refrigeration and Air Conditioning
●				●	●	●			●			●		●	●	Automotive (Dehydration, Charging and Test)
●					●	●			●						●	Electrical (Encapsulation, ...)
				●												**Semiconductor Process Vacuum**
●				●	●	●	●		●	●					●	Silicon Semiconductor
●				●					●						●	Compound Semiconductor
●				●			●		●						●	TFT-LCD Displays
●									●						●	MEMS
●				●			●		●						●	Crystal pulling
				●												**Thin-Film Deposition (non-Semiconductor)**
●					●	●	●		●	●		●			●	Glass/Web/Optical
●				●			●		●						●	Data storage (CD, DVD, Hi Def. Disc, ...)
●				●					●						●	Magnetic Data Storage (HDD)
●				●					●						●	Thin Film Heads
●				●	●	●	●		●	●		●			●	Surface Coating (wear protection, decorative, ...)
●				●			●		●	●					●	Display Coatings (OLED, FED, PDP, SED, ...)
																Solar
●				●	●	●	●		●	●		●			●	Photovoltaic Solar[3]
●				●											●	Thermal Solar (Solar Water heaters, ...)
●									●						●	Crystal growth (re-melt, ...)
				●												**Instrumentation Manufacturers**
				●					●							Mass Spectrometers
				●					●							Electron Microscopes
				●	●	●			●	●						Leak Detectors
					●	●			●							Surface Analysis
				●	●	●			●	●						Gas Analysis
				●												Metrology/Inspection/Defect Review systems[4]
				●												Focused Ion Beam systems
															●	Electron Beam systems
																X-Ray Analysis
																MRI and NMR
									●							Sample preparation[5]
																R & D
					●	●			●	●		●	●			Universities
									●	●			●			Government Labs
									●	●		●	●			Scientific Research Laboratories
		●							●				●			Space Simulation
											●					**Plastic production/processing**
																Hydrogen technology

Applications Vacuum Technology

	Rough Vacuum	Packaging (except Food)	Central Vacuum	Printing and Paper Handling	Pick and Place	Conveying	Air sampling	Medical	**Process Vacuum**	Chemical	Petrochemical	Pharmaceutical	Plastics	Food	Beverage	Textile	Paper	Ceramics	Freeze drying	Energy (Wind, Nuclear, Steam turbines, ...)	**Industrial Vacuum**	Vacuum Metallurgy[1]	Vacuum Heat Treatment[2]	Laser Technology	Electron Tubes	TV Tubes	Lamps and Bulbs
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MAN Energy Solutions SE www.man-es.com				●							●						●										
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MTA Deutschland GmbH www.mta.de		●		●																							
Pfeiffer Vacuum GmbH www.pfeiffer-vacuum.com						●		●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●
Piab Vakuum GmbH www.piab.com		●	●	●	●	●		●								●											
ITT Rheinhütte Pumpen www.rheinhuette.de											●		●				●										
RKR Gebläse und Verdichter GmbH www.rkr.de		●	●	●	●	●		●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●
SBS Metalltechnik GmbH www.sbs-metalltechnik.de						●														●		●	●		●		
SMC Deutschland GmbH www.smc.de		●		●	●	●	●	●		●	●	●	●	●	●	●	●							●			
STASSKOL GmbH www.stasskol.de		●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●		●	●				

1 (Metal Degassing, Melting, Re-melting, e-beam welding, casting, ...)

2 (Brazing, Carburising, Nitriding, Quenching, ...)

3 for Semiconductor including focused ion beam systems and electron beam systems

		●	●		●	●				●		Industrial leak detection
●					●	●		●		●		Refrigeration and Air Conditioning
●	●		●		●	●		●		●		Automotive (Dehydration, Charging and Test)
			●		●	●				●		Electrical (Encapsulation, ...)
												Semiconductor Process Vacuum
						●	●			●		Silicon Semiconductor
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						●				●		MEMS
						●	●			●		Crystal pulling
												Thin-Film Deposition (non-Semiconductor)
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						●				●		Data storage (CD, DVD, Hi Def. Disc, ...)
						●				●		Magnetic Data Storage (HDD)
						●				●		Thin Film Heads
		●				●	●	●		●		Surface Coating (wear protection, decorative, ...)
		●				●				●		Display Coatings (OLED, FED, PDP, SED, ...)
												Solar
		●				●				●		Photovoltaic Solar[3]
●				●		●				●		Thermal Solar (Solar Water heaters, ...)
						●	●			●		Crystal growth (re-melt, ...)
												Instrumentation Manufacturers
						●				●		Mass Spectrometers
						●				●		Electron Microscopes
						●				●		Leak Detectors
						●				●		Surface Analysis
						●				●		Gas Analysis
						●				●		Metrology/Inspection/Defect Review systems[4]
						●				●		Focused Ion Beam systems
						●				●		Electron Beam systems
						●				●		X-Ray Analysis
						●				●		MRI and NMR
						●				●		Sample preparation[5]
												R & D
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	●	●			●	●		●		●		Government Labs
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Imprint

Imprint

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E-Mail ulrike.maetje@vdma.org
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Responsible editor
Dipl.-Wirt.-Ing. Christoph Singrün

Frequency of publication
annual

Picture credits
Cover: VDMA Services GmbH
Page 4: HERMETIC-Pumpen GmbH
NEUMAN & ESSER GROUP
Header: VDMA Services GmbH

Publishing house
VDMA Services GmbH
Lyoner Str. 18
60528 Frankfurt am Main
Germany
Phone +49 69 6603-1595
E-Mail verlag@vdma.org
Internet www.vdma-verlag.com

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Design and Production
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Printing
Druck- und Verlagshaus
Zarbock GmbH & Co. KG
Frankfurt am Main

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Compressors, Compressed Air and Vacuum Technology

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vf 800325-e