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Pumps and Compressors for the World Market 2014
with Compressed Air and Vacuum Technology
Content

4 Editorial: Striking a new course
6 German pump and compressor manufacturers in 2014: Still heading for growth
10 Blue Competence – VDMA’s sustainability initiative picks up pace
12 Looking ahead to the International Rotating Equipment Conference 2016
14 Efficient, safe, convenient: VDMA Building Systems Forum
17 Introducing the Pump Research Fund (FFP) and the Vacuum Technology Research Fund (FFVak)
20 Energy efficiency: the VDMA as reliable partner
24 Part I: Pumps & Systems
24 New submersible pump motors for highest requirements
29 Multiphase pumps for energy-efficient water and wastewater treatment
37 Piston diaphragm pumps to remove and transport sludge and sediment
45 Metering technology for biogases and biofuels
52 Screw pumps in tank farms
58 Intelligent design for hygienic pumps: from barrel emptying systems to dosing
66 Pumps & Systems: products & applications
70 Pumps & Systems: companies & range of applications
78 Part II: Compressors, Compressed Air & Vacuum Technology
78 Radial turbines for energy generation from geothermal resources or waste heat recovery
86 Process air production with highest energy efficiency
91 The world’s largest vacuum system: CERNs Large Hadron Collider
97 Reducing carbon footprint with the right vacuum system
103 Compressors, Compressed Air & Vacuum Technology: products & applications
106 Compressors, Compressed Air & Vacuum Technology: companies & range of applications
114 Brand name & trade fair register
118 List of advertisers
105 Imprint
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Pump and compressor manufacturers: Striking a new course

Dear customer, dear reader,

The sixth edition of “Pumps and Compressors for the World Market” in 2014 strikes a new course. Together with the well-proved printed magazine, for the first time we also offer an E-Magazine, again in German and English. This “speaking book” offers possibilities for supplementing the printed magazine with additional information, video statements and image films (www.vdmashop.de/puco).

“Pumps and Compressors for the World Market 2014” still provides information about technical solutions and new possible uses for pumps + systems, compressors, compressed air and vacuum technology. Piston diaphragm pumps for sludge transport or radial turbines for generating geothermal energy are just two of the numerous applications for pumps and compressors presented as examples in this publication.

This issue owes its existence to expert, committed authors from among our membership. It also includes reviews of significant topics for the engineering sector, such as sustainability, research and energy. Expressive illustrations and a user-friendly layout give a neutral presentation of the extraordinary capabilities of our member companies. The authors and contact partners named in the magazine will gladly deal with your enquiries about new products and technical innovations described in the publication.

Would you like to know which customer branches a certain manufacturer serves? Then take a look at our clearly organised competence matrix that is featured in the proven manner next to the magazine’s technical features. This gives readers a good overview of the extensive information available on the VDMA E-Market (www.vdma-e-market.com). This highly successful online platform which currently has more than 250,000 available products helps users to make an efficient, up-to-date search for manufacturers via products and/or applications and possible uses. It is also possible to contact the provider directly, simply using the link to the manufacturer website or by sending an enquiry by e-mail.

In 2014, the German engineering sector and the associations Pumps + Systems as well as Compressors, Compressed Air and Vacuum Technology will be present with their own stands at trade fairs in Germany and abroad. The trade show highlight in Germany is the IFAT, the world’s leading trade fair for water, sewage, waste and raw materials management.
The VDMA is organising more than a dozen German pavilions at events abroad with a focus on water, sewage, chemistry and petrochemistry together with oil and gas. Such involvement abroad helps to cultivate new market potential in good time and on a global scale, which is important for consolidating the good position and reputation of our branches.

Dr. Sönke Brodersen  
Senior Vice President Research KSB AG  
Chairman of the VDMA association Pumps + Systems

Alexander Peters  
Managing Partner of the NEUMAN & ESSER GROUP  
Chairman of the VDMA association Compressors, Compressed Air and Vacuum Technology

German pump and compressor manufacturers enjoy a high reputation worldwide thanks to their capabilities and problem solving quality.
Still heading for growth

German pump and compressor manufacturers in 2014
Dipl.-Wirt.-Ing. Christoph Singrün and Dipl.-Volksw. Ulrike Mätje

In 2013 the manufacturers of liquid pumps operated slightly above the turnover level of the previous year, while the manufacturers of compressors, compressed air and vacuum technology found their turnover eleven percent above the level of 2012. For 2014, pump manufacturers expect to see 1 % growth, with 2 % growth in turnover for compressors, compressed air and vacuum technology.

Liquid pumps: production continues to grow

In 2011, according to the Federal Statistical Office the production of liquid pumps (without hydro pumps) reached € 4.5 bn, which is nearly the record level of 2008. This value was slightly exceeded in 2012 (+0.5 %) with an overall value of € 4.6 bn. Rotary pump manufacturers took the biggest piece of the cake with more than 40 %, while manufacturers of oscillating or rotating displacement pumps accounted for 10 % each. In the first three quarters of 2013, production generated € 3.5 bn. This is a growth of 2.6 % compared to the same period in the previous year. The volume for the whole year 2013 is estimated at € 4.7 bn.

The incoming order statistics for liquid pumps obtained from the VDMA members reflects the economic situation of German pump manufacturers (Fig. 1). Demand throughout 2013 was only slightly below (–1 %) the level in the previous year, with a slight decline in domestic business compared to exports which remained on the same level as in the previous year. In January 2014, capacity utilisation, which is a good indicator for the cushion of orders, was in the “lower” range with 81%. Turnover generated in 2013 was 2 % higher than in the previous year.

Germany still export world champion

Liquid pump exports also saw moderate growth in 2013, as well as production. In the first eleven months of 2013, Germany supplied 6.1 % more liquid pumps (without hydro pumps) abroad.
than in the same period for the previous year, corresponding to an export volume of € 4.7 bn. It looks as if a volume of € 5.1 bn will be achieved for the whole year 2013. And so Germany remains unchallenged export world champion. In the world trade volume of around € 31 bn (2012), German manufacturers account for about 16% (Fig. 2), well ahead of the USA and China (with 12% each).

Europe remains the key sales market for German liquid pumps, accounting for altogether around 58% of exports. Asia accounts for a further quarter of sales, with 9% of exports going to North America. German pump exports to North America saw a clear increase in 2012. Demand for German pumps grew particularly in the USA with 11.7%. Mexico nearly doubled its imports, but this accounts for only 8% in the total volume of exports to the NAFTA. There has been a clear decline in growth in Asia. Increases were only registered in deliveries to Singapore and Thailand. Exports to Africa declined for the third year in succession. In 2012, the main customer countries South Africa and Egypt imported 5% respectively 16% fewer pumps from Germany than in 2011. The key customer countries for Germany in 2012 were China, the USA, the Czech Republic, France and Russia (Fig. 3).

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Compressors, compressed air and vacuum technology: production is growing again

According to the Federal Statistical Office, in 2011 compressors, vacuum pumps, compressed air machinery and tools were produced at a value of €4.9 bn. This value decreased slightly in 2012 (–1.8 %). Turbocompressors have a significant share of production with around 38 %, followed by rotating displacement compressors with 19 %, vacuum pumps with 15 % and parts for vacuum pumps and compressors with 13 %. In the first three quarters of 2013, production generated €3.9 bn. This is a growth of 10.7 % compared to the same period in the previous year. The volume for the whole year 2013 is estimated at €5.2 bn.

The incoming order statistics obtained from the VDMA members for the overall year 2013 show demand to be 8 % above the previous year’s level, due in particular to good domestic demand (Fig. 4). Turnover generated in the overall year 2013 was 11 % higher than in the previous year.

Germany still No. 1 for exports

Given a slight decline in production, exports by German manufacturers of compressors, compressed air and vacuum technology continued to increase in 2012. In 2012, Germany supplied 5.1 % more goods abroad than in 2011, corresponding to an export volume of €5.2 bn. Volume for the whole year 2013 is expected to be on a similar level.

Germany’s world trade share still accounts for 15 % (Fig. 5) of the total global trade volume, which in 2012 amounted to €33.6 bn. As in the previous year, Germany is followed by the USA (11 %) together with China and Italy (each with 8 %).

Europe remains the key purchaser of German compressors, compressed air and vacuum technology. More than 51 % of exports remain on the European continent, of which 81 % go to the EU. East and South-East Asia is the second major purchasing region. Here development depends crucially on China’s economy, which took more than 60 % of exports to this region in 2012. Purchaser structures on the American continent...
Economic Development

Companies, coordinated by the VDMA, together with maintaining a regular presence on promising foreign markets, including for example the promotion of German exports in the German pavilions. There is also an increasing focus on sustainable production and sustainable products. This results in the constant further development of products to ensure they remain competitive on a global scale.

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Pumps and compressors “made in Germany” still in demand

Defending and expanding its leading position on the world market remains the declared objective for Germany’s pump and compressor industry in 2014. Constant effort will be needed to achieve this, including joint pure research by the German pump manufacturers remain the unchallenged export world champions.

Improving efficiency is a key focus of our development work. Our target is to increase pump performance while simultaneously decreasing the energy input. Thus a pump system, e.g. for a replacement, can be dimensioned significantly smaller and be still more efficient.

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Dr. Franka Schneider, Research Engineer Fluid Mechanics
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Blue Competence – VDMA’s sustainability initiative picks up pace

Dipl.-Volksw. Ulrike Mätje

Shorter standstill times due to high-strength materials in pump cogwheels and plain bearings, or recovering helium from leak testing processes – these are just two practical examples of implemented sustainability. “Do good and talk about it!” – that’s the motto of the VDMA’s Blue Competence sustainability initiative. It positions the engineering sector as the enablers in the economy – for both sustainable production and also sustainable products. Meanwhile around 400 companies have joined in with the initiative which was launched in October 2011, with participation increasing all the time.

Together we’re strong

Companies from 38 product areas together with their associations and organisations are involved in Blue Competence, where they undertake to fulfil verifiable sustainable criteria. VDMA Pumps + Systems as well as VDMA Compressors, Compressed Air and Vacuum Technology are also involved. Blue Competence aims to bring about greater transparency, facilitate orientation and give certainty to all those looking for sustainable solutions and products or sustainably acting companies.

Website with double benefit

A comprehensive overview of the campaign can be found on the website www.bluecompetence.net. A search function has now been added to give the website a useful value in the long-term.
There is a standard layout for success stories which can be used both as .pdf on the website and also by companies as flyers for trade-fairs etc. Companies involved in Blue Competence that submit their success stories in future will therefore see a double benefit: the success story will be presented in the framework of the Blue Competence website and can also be used for the company’s own PR work.

**Implemented sustainability**

One important criterion for submitting success stories consisting in filling the fact box (blue box on the back of the flyer) with figures and verifiable facts. Background: the success stories submitted by Blue Competence partners act as credible, verifiable evidence of their sustainability according to the Blue Competence usage agreement. External stakeholders such as the political sector, customers and the general public demand measurability and verifiability. The facts and figures help to take this into account.

Submitted success stories for pumps + systems, compressors, compressed air and vacuum technology are also available online in the E-Magazine.

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www.bluecompetence.net
Looking ahead to the International Rotating Equipment Conference 2016

After the conference is before the conference. In autumn 2016, the “International Rotating Equipment Conference – Pumps and Compressors” will be taking place for the third time, four years after the last event which was held in Düsseldorf at the end of September 2012. For the third time the VDMA associations Pumps + Systems and Compressors, Compressed Air and Vacuum Technology will join forces with the EFRC (European Forum for Reciprocating Compressors) to combine their three forums: the 11th Pump Users International Forum, the 4th Compressor Users International Forum and the 10th EFRC Conference.

In focus again: rotating equipment

The International Rotating Equipment Conference is known for pursuing the well-used practical approach of forming more and more working teams to cover the whole field of rotating equipment. “Even more application-oriented and international than in 2012 – that’s the motto for 2016”, is how Christoph Singrün, Managing Director VDMA Pumps + Systems and Compressors, Compressed Air and Vacuum Technology explains the event which is held in English and which was attended by a good 850 participants from more than 40 countries last time. Users and operators made up an impressive share of the conference participants, accounting for a good 30%.

Established programme

The concept which has been so successful in the past is being further optimised. Together with many specific contributions on current aspects covering pumps, compressors and compressed air/gas systems, this time once again vacuum technology will also be on the agenda. Panel dis-
Discussions will provide an opportunity to discuss current issues with experts. In addition, graduates can enter into informal contacts with potential future employers.

The two-day forum will also be accompanied once again by a technical exhibition. In 2012, more than 70 companies presented the whole range of pump, compressor and vacuum technology on around 700 square meters. The concept of “Meeting Points” within the exhibition areas is also being maintained. This lets participants continue their discussions of the technical contributions or obtain information about new products.

Outlook

Impressions from 2012 and more information about the forthcoming event in autumn 2016 can be found on the conference website at www.introequipcon.com

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THE INTELLIGENT SYSTEM APPROACH EXCLUSIVELY FOR PUMPS
Since September 2011, the Building Systems Forum has been offering an interdisciplinary, pre-competition approach by pooling the expertise of those associations and working groups in the VDMA that supply their products and services for the building systems sector. The forum thus provides the basis for coordinated solutions in building systems. Building Systems account for between 400 and 500 VDMA member companies according to their product portfolio.

The building sector is one of the key sectors of the economy. The construction of buildings accounts for a good € 180 bn each year. The VDMA member companies whose products are also supplied for building systems generate a production volume of around € 15 bn p.a. The way buildings are equipped with systems and technology makes a vital contribution to the conditions in which people live and work in developed societies. At the same time, the building sector is responsible for around 40 % of primary energy consumption.

The VDMA Building Systems Forum covers the following areas:
- Valves
- Lifts and escalators
- Automation + management for house + building
- Decentral energy supply
- Maintenance
- Refrigeration
- Air conditioning and ventilation
- Pumps and systems
- Security systems
The VDMA Building Systems Forum thus covers the main elements of technical building systems and the corresponding services. The need for safety and comfort together with the necessary efficiency of resources and energy are key issues for the forum which thus provides a basis for coordinated solutions in building systems for both residential buildings and commercial and industrial buildings. Only an integral, multi-disciplinary approach will be able to cope with the current challenges arising from climate protection and energy policy. This is the key to reconciling competing interests, e.g. between investors and building users. The forum has two external bodies - the Steering Committee and the Building Systems Economic Committee which meet every six (Steering Committee) or twelve months (Economic Committee).

**Building Systems Steering Committee**

The Steering Committee plays a central role; it is currently made up of representatives from twelve companies and is chaired by Uwe Großmann, Head Solutions & Services Portfolio, Siemens AG, Infrastructure & Cities Sector, Building Technologies Division. In July 2013, the Steering Committee drew up a set of building systems guidelines in cooperation with the VDMA Building Systems Forum. The guidelines aim in particular to fulfil the climate protection targets while permitting effective building planning and value-enhancing refurbishment of existing buildings. “Smart, multi-disciplinary building systems play a key role”, says Dr. Thomas Schräder, VDMA spokesman for the Building Systems Forum. “At the same time, this is the basis for integrating buildings in the smart energy networks of the future.”

In implementing the energy efficiency and climate protection targets, attention must increasingly turn to the non-residential building sector. Up to now, this sector including all public properties has been neglected for the most part. And yet it is much easier to tap into potential efficiency here, for example through qualified energy-saving contracting. Taking life cycle costs as a strict focus is prerequisite.

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But reliable political framework conditions are needed to implement integrated solutions today and in future. “Our demands are also an invitation for talks with the political sector”, says Schräder.

The demands include among others:
• Naming a body with central responsibility. This will permit appropriate coordination of the various aspects of optimum building design – resource efficiency, security, quality of life and value preservation – on a national and European level.
• Together with the efficiency of energy and resources, attention also has to be given at the same time to aspects such as health protection, operational reliability and barrier-free access.
• Production processes in industry and manufacturing that are relevant to energy consumption must be integrated in the energy management and operation of buildings.
• It is vital for attention to focus on the non-residential building sector.
• The public sector must act as a role model, as demanded by the EU in the Energy Efficiency Directive.
• Any kind of funding must apply to all technologies in all areas.
• Observed deficits in quality must be dealt with by new, integrated training and study concepts.

Together with these concrete demands, the Building Systems Forum also draws attention to important aspects in the various sub-areas.

**Efficiency**

• Refrigeration and air conditioning: optimisation e.g. of compressors, heat exchangers, heat recovery and operations management offers potential savings of up to 40%.
• Smart building automation offers potential savings of up to 50% depending on the building type.
• Experience shows that the consumption of heating energy can be cut back by around 10% already by replacing old thermostat heads.
• Modern lift technology offers an efficiency advantage of about 40% compared to the average existing systems.
• Smart combined heat and power systems can safeguard both the heating and the power needs of buildings.
• Modern pumps and pump systems stand out with particularly low energy requirements.
• Sustainable drinking water use and hygiene can be planned. Here it is crucial to select the right components with professional installation of the drinking water systems.

**Safety**

Modern fire safety and air purification systems make a major contribution to safe and cozy living, working and production conditions.

**Comfort and barrier-free access**

Lifts and escalators as part of energetically appropriate building systems warrant barrier-free access to buildings. In the context of demographic change, increasing significance is also being attributed to age-appropriate bathroom solutions.

**Building systems: experiencing tomorrow today**

Persistent urbanisation, world population growth and increasing life expectancy together with environmental and climate protection demand innovative solutions in the field of building systems. These are already available on the market today. In future, buildings will not only consume power but also generate it with smart control and power sales concepts to improve their monthly balance sheet. In this way, the smart buildings of tomorrow also act as crucial control points in a smart infrastructure.

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Introducing the Pump Research Fund (FFP) and the Vacuum Technology Research Fund (FFVak)

Harald Frank and Jürgen Eisenreich

For many years, the VDMA has been successfully involved in organising and handling cooperative research projects. In the framework of pre-competition industrial joint research, it works together with the Forschungskuratorium Maschinenbau e. V. (FKM) (Engineering Research Board) and the research associations of the various branches to offer two efficient, beneficial cooperation platforms: the Pump Research Fund (FFP) and the Vacuum Technology Research Fund (FFVak).

The Pump Research Fund

It was already back in 1973 that the VDMA association Pumps + Systems set up the Pump Research Fund (FFP) to conduct joint research in pump construction. The FFP is part of the VDMA’s research network. Joint research projects are mainly implemented and financed with public sector funds.

The European Commission estimates that throughout the EU, pumps and pump systems...
Although the products of Germany’s pump industry already embody the highest technological standard today, German manufacturers as technology leaders see their responsibility for pursuing specific research activities to save resources in both the production and operation of the pumps, thus protecting the environment and offering sustainable concepts.

**Promoting future technology**

System efficiency, demand-oriented power pick-up, optimised efficacy, intelligent control and regulation concepts, optimised selection and use of materials, Computational Fluid Dynamics (CFD) and reducing environmental influences are just some of the key words describing the scope of research activities in the Pump Research Fund.

At present, 37 companies have undertaken to pursue or are involved in pursuing future-oriented research for the sustained protection of resources and the environment.

Together with the direct benefit for the companies and the environment, one major side-effect of pre-competition joint research consists in improving the financial situation of Germany’s universities. In Germany’s university system, the research units increasingly depend on obtaining external funds to secure the institute’s existence. Accordingly, the Pump Research Fund helps to sustain and expand top-level research in Germany. This also fosters the next generation of qualified engineering for Germany’s pump manufacturers, which in turn forms the basis for future technological leadership.

consume around 30% of the energy provided by electric drives (SAVE study, 2000). Within the EU, electric drives in turn are responsible for approx. 30% of all electrically generated energy, so that pumps and pump systems consume about 10% of electrically generated energy or 280 TWh p.a. in Europe alone. Pumps and pump systems therefore count among the major energy consumers.

Pump manufacturers have to invest in research and innovation, among others in view of the statutory demands and minimum efficiency requirements made of pumps and pump systems - take for example the Energy using Products (EuP) / Energy related Products (ErP) Directive.
The Vacuum Technology Research Fund

The Vacuum Technology Research Fund (FFVak) in the VDMA is a bit younger. The founding meeting of the FFVak was held on 20 November 1998, at that point in time with a main focus on vacuum pumps. The FFVak is also embedded in the VDMA’s research network; in the framework of pre-competition industrial joint research, it works together with the Forschungskuratorium Maschinenbau e. V. (FKM) (Engineering Research Board) to offer its members an interesting platform for proceeding today to examine the requirements that vacuum technology products will face tomorrow.

Since it was founded, altogether ten joint research projects have been concluded at a value of around €1.5m. These were carried out mainly in cooperation with the AiF (Consortium of Industrial Research Associations e. V.), which provides the corresponding funds. The results obtained from the different projects, some of which are financed with the companies’ own funds, give the participating firms a competitive lead while at the same generating their own next generation of engineers as a side effect. In many cases, those involved in a project will subsequently find employment immediately afterwards with one of the participating companies.

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http://euro.vdma.org/en/forschung

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Energy efficiency: the VDMA as reliable partner

Friedrich Klütsch

Following a brief period when energy efficiency temporarily receded into the background with attention focusing on alternative energy sources with their subsequent problems (grid expansion, storage issues), it is now currently enjoying a renaissance. After all, energy efficiency is the “energy form” where every individual and every branch of industry including engineering can assume responsibility for making a major contribution. The VDMA associations Pumps + Systems as well as Compressors, Compressed Air and Vacuum Technology have been supporting their members in this respect long before the efficiency activities of the European Union. By launching the initiative “Druckluft effizient” in 2001, the compressed air industry was one of the first industries in the mechanical engineering, that introduced the topic of energy efficiency to customer circles.

Since 2005 the VDMA association Pumps + Systems has actively supported its member firms in implementing the energy efficiency projects launched by the EU Commission in the course of implementing the Ecodesign Directive. Since 2011 – when compressors became the focus of a preparatory study – the VDMA association Compressors, Compressed Air and Vacuum Technology has formed a working group that aims to become involved in drawing up a technically sound, effective regulation for the machines that are in focus here.

Energy efficiency: the lowest cost energy source

It is quite apparent that energy which is not consumed does not have to be generated in the first place. Furthermore, energy efficiency is completely independent of the type of energy generation. Regardless which type of energy generation is given preference by society or the political sector, energy efficiency must therefore be the least critical "energy form". It needs no additional effort on the part of those responsible for subsequent aspects and, when there is no time pressure along the lines of premature change in product, it can be implemented in the course of on-going product development along essentially cost-neutral lines. Energy efficiency is the "energy form" for which every individual and every branch of industry including engineering can assume responsibility for making a major contribution.

Global issue

In recent years there has been increasing pressure from the political sector and the markets for presentable results to be produced more quickly. Global climate summits are held, attended by hundreds of delegates who fly all around the planet with the aim of agreeing on binding concessions for saving energy. Blame is apportioned in a manner that is hardly helpful. Some try to impose restrictions and regulations to bring about an equality that will never exist. Others are held captive by their growth strategies and see the necessary changes as an attack rather than an alternative. On the one hand, it seems completely illogical to let the developing countries make the same mistakes that the so-called industrial nations made in the past and in some cases still make today. On the other hand, the highly developed countries offer no alternatives on the path to prosperity.

Global climate summits of recent years failed among others because too many demanded too much and too many put energy efficiency and sustainability on a par with having to do without economic growth. But no politician can or will make any such commitment. Why doesn’t anyone ask “Is this true at all?”, or why should mistakes be repeated when better solutions and the necessary know-how is already available? Strict refusal is certainly not the right solution!
Instead, the aim should consist in being at the forefront when the day comes for achieving growth in a more ecologically sound fashion, while being able to serve the markets created and used by future generations. The fact that markets change sooner or later – some shrink or disappear completely and others emerge – is nothing new. The market for energy-efficient products is already here! In certain markets, it is already not possible to sell many products without a label or some other sign of energy efficiency.

**Commitment shown by the VDMA members**

The member companies of the VDMA associations Pumps + Systems as well as Compressors, Compressed Air and Vacuum Technology are aware of this and play an active role in shaping the requirements for a more efficient and “environmentally compatible” generation of products. Some of the companies that play an active role in this work are listed on the stock exchange and all of them are profit-oriented. In this work, which is admittedly not always positive, they see a great chance for putting their companies in a successful position on the market in the medium and long term.

**What compressor manufacturers are doing ...**

Formally, compressor manufacturers have taken up the same approach used eight years ago by the pump manufacturers. In this procedure, a central role is played by the specific European sector committee (Pneurop). An overall working group that reports directly to the Board is the central contact partner for the European Commission, the respective study author and the institutes or bodies involved in the process (e.g. standardisation bodies). The members of the overall working group ensure that the representatives of the Member Countries receive the necessary information from the working group. Specific product and application aspects are elaborated by experts. The whole thing is a time-consuming and labour-intensive matter but this is gladly taken into account to avoid being affected by implementation measures that the industry cannot accept. By the way, Brussels sells implementation of the Ecodesign Directive and the initiated processes as an open, democratic approach with the greatest possible participation by industry.

It would be a gross strategic mistake not to be involved in this game, even if the way the “rules” are interpreted here or there can cause irritations, or the expertise of other participants seems dubious or the whole process appears
ENERGY EFFICIENCY

Since compressors became the focus of a preparatory study, the VDMA association Compressors, Compressed Air and Vacuum Technology has been pursuing the objective of getting involved in drawing up a technically sound, effective regulation for the machines that are in focus here.

industry's proposal for the application range – has been completed. The schedule now features the follow-up measures of the last stakeholder meeting, the Regulatory Committee (without direct industrial participation) and the draft bill. It is not certain whether everything will be completed by the end of 2014 because of the forthcoming European elections in summer 2014. Until the Regulatory Committee meets, the motto is therefore to keep on the ball. The same applies to the preliminary study

• ENER Lot 31: Products in motor systems outside the scope of the Lot 30 and the Regulation 640/2009 on electric motors, in particular compressors, including small compressors, and their possible drives

They are involved in open dialogue with the study authors, the representatives of the Energy Directorate which is responsible for this study, and the representatives of the German government. The actors are known and most of the work – data acquisition and verification and

• ENER Lot 30: Products in motor systems outside the scope of the Regulation 640/2009 on electric motors, such as special purpose inverter duty motors (asynchronous servo motors), permanent magnet motors, motors cooled by their load (fans), including motors and products under Article 1, Points 2(b), (c) and (d) and including drives, such as soft starters, torque or variable speed drives (VSD) from 200 W–1000 kW. The study should also cover motors in the scope of the Regulation 640/2009 from 750 kW– 1000 kW.

This preliminary study is also being accompanied by both associations through the respective sector committees. Even if the compressor or pump manufacturers are not responsible for most of the motors, it is still extremely important for the branch to know the future statutory requirements for the motors as soon as possible in order to take an active approach in good time if the need arises.

What pump manufacturers are doing ...

Apart from the motor study Lot 30, the pump manufacturers that were already affected by the first preliminary study ENER Lot 11 on heating circulation pumps and water pumps are currently playing an active role in two pump-specific preliminary studies:

• ENER Lot 28: Pumps (extended product approach including motors, VSD and controls, where appropriate) for private and public waste water (including all stages including buildings, networks and treatment facilities) and for fluids with high solid content

The VDMA association Pumps + Systems has started work at TU Berlin to obtain qualified efficiency statements about pumps in waste water applications.

• ENER Lot 29: Pumps (extended product approach including motors, VSD and controls, where appropriate) for private and

to be anything but “open” and “democratic”. At the moment, the compressor manufacturers are accompanying the preliminary study

• ENER Lot 28: Pumps (extended product approach including motors, VSD and controls, where appropriate) for private and public waste water (including all stages including buildings, networks and treatment facilities) and for fluids with high solid content

• ENER Lot 29: Pumps (extended product approach including motors, VSD and controls, where appropriate) for private and
public swimming pools, ponds, fountains and aquariums, as well as clean water pumps larger than those regulated under Lot 11.

Both studies proceed in the usual fashion with an intensive exchange of views through the sector committee EUROPUMP. But with Lot 28, the pump manufacturers are moving beyond the realm of research backed by existing research projects. As far as clean water is concerned, scientifically sound findings have been available for years now which can be fed into the legislation process. But as far as waste water is concerned, right at the start the question arises: “What in fact is waste water?” With the tender notice for the preliminary study, the association Pumps + Systems started work at TU Berlin, financed by the research fund’s own resources, with the aim of obtaining verifiable statements for pumps in waste water applications within the remaining period of time. Following an initial literature research that produced sobering results, last year substantial steps were taken to obtain reproducible test methods by the end of 2015 that will supply a definition of waste water together with calculation methods to permit qualified efficiency statements for such pumps. Here it is worth noting that the availability of a waste water pump and its maximum possible efficiency are contradictory requirements. Even if it will still take a good two years before a possible regulation comes into effect, a lot of work and time will still have to be invested in order to meet the companies’ individual requirements.

Outlook

The engineering sector is already feeling the initial impact of the announced expansion of the Ecodesign Directive from the aspect of manufacturing/resources conservation and recycling to be incorporated in a product environment carbon footprint. This entails a new discussion of the principles involved, starting with the framework conditions via the rating and weighting of product-specific aspects, leading to the implementation and documentation of these statements. It can only be hoped that this discussion entails sufficient expertise and will remain free of exaggerated demands, self-opinionated self-marketing and above all, free of ideological competition. The demand for such statements is sensible and worthwhile, but it doesn’t all have to be done simultaneously by everybody in next-to-no time. When it comes to acknowledged experts, resources are limited, and good things are known to take their time. Until then, let us focus on the energy efficiency of our products as the most sustainable option for saving energy at the least cost.

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New submersible pump motors for highest requirements

Ludger Gottkehaskamp, Johann Neiszer and Georg Cichon

For the submersible region of mines, water wells and subsea applications pump motor units of 12 inch size with significant improvements have been developed. On the pump side, the efficiency levels could be raised from 74 to 80 % and on the motor side from 88 to 93 %. With the pump, the delivery head per stage was almost doubled. In the motor, a performance improvement of up to 30 % was achieved with the same size. These performance increases led to improvements of the overall efficiency levels from 65 to 74 %, which directly affects significant lower energy consumption and thus a better efficiency.
Submersible pump motor units, which consist of submersible centrifugal pumps and submersible asynchronous motors, are used in many areas for the conveyance of waters of different water quality. The performances range from a few kilowatts to some megawatts, the flow from a few to some thousands of cubic meters per hour and the delivery heads to over 1,000 m. For many years, such submersible units are used in all parts of the world in order to drain, for example, mine pits for coal, rare earth and gold. In arid zones, these units are used for pumping water from wells for the potable water supply and field irrigation. This article describes the results from a development project, which were achieved with a new pumping and motor series.

Requirements of submersible pump motor units

Customised requirements and technical innovations are considered in the development, sizing and manufacturing of submersible pump motor units. Depending upon operating condition of the units, certain requirements for the pump and motor must be fulfilled apart from high efficiencies, different material adjustments, simple assembly and disassembly, which were listed in the following.

Requirements for submersible pumps:
- Steady rising pump curve of flow and head
- Maximum hydraulic head per stage
- Minimal material use per stage
- Usable at different pump speeds

Requirements for submersible motors:
- Applicable in connection with a frequency converter
- High specific power per motor volume
- Internal cooling in connection with heat exchanger and suction jacket
- Water or glycol water mixture as filling medium

Energy process in the submersible unit

In Fig. 1 the relationship of the sub-units pump and motor has been illustrated. The shaft power supplied to the pump (P2 = shaft power, Equ. 1) puts the pump in motion and promotes a flow (Q) at a given delivery head (H) analogous to the pump curve. The ratio delivery head multiplied with flow, gravity and density to shaft power is expressed through \( \eta_P \) (pump). The power from the electrical net (P1) is fed into the motor. This power is largely transferred into rotation (P2 = shaft power) and to a very small proportion in losses (e.g. heat). The ratio of power used (P2) to net power (P1) is illustrated by the motor efficiency \( \eta_M \) (Equ. 2). The value crucial for the operator is shown by the overall efficiency level \( \eta_{tot} \) (Equ. 3) of the unit. This number finally reflects which energy is used or remains unused.

\[
P_1 = \text{Net power} \\
P_2 = \text{Shaft power} \\
g = \text{Gravity acceleration} \\
\rho = \text{Density} \\
H = \text{Head} \\
Q = \text{Flow} \\
\eta_M = \text{Motor efficiency} \\
\eta_P = \text{Pump efficiency} \\
\eta_{tot} = \text{Total efficiency} \\
\]

\[
P_2 = \frac{\rho \cdot g \cdot H \cdot Q}{\eta_P} \\
\eta_M = \frac{P_2}{P_1} \\
\eta_{tot} = \eta_P \cdot \eta_M = \frac{\rho \cdot g \cdot H \cdot Q}{P_1} \\
\]

Fig. 1: Parameter for pump and motor, energy process within the aggregate

Fig. 2: Pump motor aggregates at commissioning (left) and as sectional model (right)
Improvement potentials in the pump motor units

Significant improvements have been realised on both the pump side and the motor side. The main influence was taken on pump and motor regarding the efficiency levels and areas of application.

Development potentials with the pump: The development of new hydraulics in connection with specific materials resulted in significantly higher pump efficiencies. The new hydraulics produced up to twice the delivery head per stage compared to the former hydraulics. The hydraulic development could be substantially accelerated by computer simulations (ANSYS). A comparison of the simulation data (CFD) with the data from the experiments was carried out in a faster manner. With the help of the Rapid Prototyping process, the feasibility of the developed pump parts could be accelerated.

The development of new hydraulics in connection with specific materials resulted in significantly higher pump efficiencies.
Development potentials with the motor: By mathematical optimisation (CFD) of the geometric conditions and improved selection of electrotechnical materials, the efficiency of the motor was increased (Fig. 3). Torques, speeds, voltages, currents were mathematically optimized under different conditions. For the same size, a performance improvement between 20% and 30% and an increase in efficiency of 2% to 5% were achieved.

The following aspects were considered during the motor optimisation:

• Selection of suitable lamination qualities
• Design of the rotor bars and short-circuit rings
• Reduction of hydraulic losses
• Improvement of the heat emission
• Performance maximisation at same size

Measurement results of the submersible pump motor units

The following requirements in the new pump series (12 inch size) with three pump sizes were aimed (flow Q_{opt}, delivery head H_{opt} in the optimum, specific speed n_q):

• The optimisation parameter efficiency has highest priority.
  • Q_{opt} = 250 m³/h, H_{opt} = 45–49 m, n_q = 42
  • Q_{opt} = 340 m³/h, H_{opt} = 43–47 m, n_q = 51
  • Q_{opt} = 420 m³/h, H_{opt} = 38–42 m, n_q = 60
• Within the range Q_{opt} ± 20%, the efficiency shall be ≥ 75%.

The measured pump curves for the new and former design show a steadily rising upward from maximum to minimum flow. In Fig. 4 the delivery head (H) was applied against the flow (Q) by a three-stage speed pump. The maximum flow amounts to 400 m³/h. The new design shows a nearly double delivery head per stage (48.6 m
Innovations & trends

per stage, 146 m per 3 stages at 340 m³/h) at optimal degree of efficiency compared to the conventional design (21.7 m per stage, 65.3 m per 3 stages at 320 m³/h). This has the consequence that fewer steps per application and thus less material must be expended for the pumping stages. The pumps with new design have a lower weight.

By mathematical optimisation of the geometric conditions and improved selection of electrotechnical materials, the efficiency of the motor was increased.

The degree of efficiency ($\eta_P$) of the pump led to an improvement from 74 % with the former design to 80 % with the new design. The degree of efficiency ($\eta_M$) of the motor could be increased from 88 % to 93 % (Fig. 6). These efficiency enhancements have led to the improvement of overall efficiency ($\eta_{total}$) from 65 % to 74 %. In addition, the delivery head per stage was increased by a factor of 2.1. In this case, this means reducing the number of stages from 7 to 3. The pump thus becomes shorter and lighter. The material consumption is lower. The assembly and disassembly is significantly simplified. The fault liability of the pump is reduced due to fewer stages.

The three developed pump 250, pump 340, pump 420 cover the flow range from 250 to 420 m³/h at the optimum. The measured efficiency levels are in the range 79 % to 81 % (Fig. 7). For all pumps, the efficiency levels are at least 75 % in the range $Q_{opt} \pm 20\%$.

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Multiphase pumps for energy-efficient water and wastewater treatment

Dr. Jürgen Holdhof

Multiphase pumps are unique products with outstanding features compared to conventional centrifugal pumps. The approach consists of using the pumps not only for transport of liquids but also for partial gas supply and as dynamic mixer for gas enrichment. Therefore this novel pump conception barely has something in common with a standard pump. Even the mode of operation does no longer comply with the common doctrine: the multiphase pumps are slightly throttled at the inlet side, in order to get automatically sucked in gas contents. With standard centrifugal pumps this inevitably would result in cavitation.

Multiphase pumps are suitable for many processes. Gassing liquids that also need to be handled by pumps occur in many applications. A large market segment is the water and waste water treatment by means of dissolved air flotation where the multiphase pumps provide the task of air saturation without the use of compressed air.
Multiphase pumps are dynamic mixers performing two functions. On the one hand liquids are being enriched with gases, on the other hand these liquid-gas mixtures are being transported. At the same time during the pressure generation in the pump a blending and an excellent gas saturation occurs. By means of following retention lines this gas saturation can be further enhanced.

The multiphase pump only is required for the gas enrichment. Static mixers are omitted. The gas is supplied directly into the suction pipe line or into the inlet flange of the pump. The pump hydraulics itself then brings the gas contents into solution (Fig. 1).

Some typical applications are:
- Dissolved air flotation with a pressure saturation system corresponding to VDMA Specification 24430, Edition March 2010
- Aeration (Bioreactors)
- Ozonation
- Oil-water separation
- Elimination of lime in the paper industry
- Mineral processing (like copper extraction)

The use of multiphase pumps provides a lot of advantages:
- The reduction of the system components and the simplification of the system design results in lower investment costs and higher operational reliability. Compared to conventional system designs compressors, pressure tanks and complex control are no longer required.
- The high efficiency improves the energy balance and reduces operating costs.
- High degrees of solution in terms of the utilised gases improve the yield of recyclable fractions.
- Good control characteristics and a wide range of application of the multiphase pumps lead to an operation that meets the requirements and avoids uneconomical method of operation.
- Process reliability is significantly increased.

Consequently the new pump conception amortises within a short period of time means that it is not only of interest for new plants but also for the retrofitting of existing plants.

Operating limits of centrifugal pumps

The usual purpose of centrifugal pumps is the transport of clean liquids. Unfortunately this ideal typical utilisation is rare under real operating conditions. It is frequently the case that the pumps also need to handle undissolved gases or vapours. On one hand the reasons may be internal to the plant, e.g. leaks in the suction pipe lines, insufficient coverage of the suction pipe line with liquid in open systems etc. On the other hand process-related requirements must also be taken into consideration. In many processing applications it is often the case that multiple phases of various media that need to be handled are present simultaneously.
Typically liquids need to be enriched with gases, liquid-gas mixtures are to be transported or gas-sing liquids are to be handled safely. Under such requirements the well-known non-selfpriming centrifugal pumps either fail or do not enable safe operation. Basically the failures here are caused by the design of the impeller. During increase of gas contents an increasingly more stable stationary gas area is formed in the area of the impeller hub that finally blocks the impeller inlet and interrupts the transport. The characteristic curve is no longer stable, even at low gas contents. Consequently such standard pumps are not suitable for meeting the before mentioned operating conditions. The process automation in particular requires a controlled and trouble-free pump operation.

Gas contents influence

The pump hydraulics of a modern multiphase pump is designed also for safe handling of gases. Furthermore in case of separate supply of liquids and gases a good mixing of the two phases resp. a high degree of dispersion is achieved.

The pump characteristic is essentially determined by the gas contents in the pumped liquid. The gas contents influences the flow rate, the pressure and the required pump power input. Increasing gas contents tend to decreasing flow rates and pump pressures but also to decreasing pump power input (Fig. 2).

Gas handling percentages of up to 30% are achieved without that the pumps are stopping operation. With regard to the process it is of advantage that the entire pump characteristic curves can be run with stable operating conditions.

Operation as a dynamic mixer

By doing so multiphase pumps provide the gas enrichment of liquids. The gas is supplied into the suction pipe line or directly into the inlet flange of the pump. If the pressure of the available gas is below that of the separate available liquid, the pump only has to be throttled at the suction side.

Increase of gas pressure is omitted. The pump operates as dynamic mixer as due to the rota-

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Pumps and Compressors for the World Market with Compressed Air and Vacuum Technology 2014
Multiphase pumps cannot only be used for transport of liquids but also for partial gas supply and as dynamic mixer for gas enrichment.

The cleaning result is significantly determined by two influence factors: the size of the micro bubbles and the amount of gas.

Fine and homogeneously dispensed micro bubbles must be created in order to collect as much floating substances as possible. Depending on the waste water quality and the saturation pressure, dispersions with bubble sizes of between 30 and 50 µm successfully achieve an ideal cleaning result. Smaller bubbles do reduce the rising speed too much whereas larger bubbles do disturb the formation of flotate (Fig. 3).

The maximum solubility of air in water essentially depends on the saturation pressure, the water temperature and the water quality. In combination with the other system components the degree of solubility of the supplied air amounts up to a maximum of 100%. The operating performance of the pump also remains stable even in case of changing flow rates and air contents enabling an exact pump control and adjustment to the regarding process.

Various gases with their specific characteristics are used depending on the particular application. For the correct pump selection the solubility of the gas in the regarding liquid is of utmost importance. As a result the solubility and therefore the level of gas feeding of air or oxygen is far below the values of carbon dioxide.

The special design of the multiphase pumps enables a direct gas input into the suction pipe line. As a result system components like compressors, pressure tanks, pumps, control devices and valves are not necessary compared to conventional systems (Fig. 4).

Typical fields of application include the treatment of oil/water emulsions, fat separation, phosphate precipitation and heavy metal precipitations as well as secondary clarifications in biological purification plants. Multistage flotation systems are also well-known for the treatment of special waste. Many plant manufacturers report that by the use of multiphase pumps savings are not only made with regard to investment volumes but also for the continuous operating costs that on average amount to between 30% and 40% compared to conventional systems depending on the plant type.

Waste water treatment by means of dissolved air flotation

Dissolved air flotation (DAF) is a proven and well recognised procedure for the treatment of water and waste water and for the recovery of recyclables as well. It serves to simply separate substances that are suspended or emulsified in liquids. In doing so saturated water is released to atmospheric pressure with highly pressurised air and guided into the waste water tank. The micro bubbles that become free during pressure release do settle on the suspended materials and float them to the liquid surface. From here they are removed by skimming devices. Consequently, the particle stream is the opposite of known sedimentation process.

Fig. 4: System design

Photo: EDUR

Source: EDUR

Pumps and Compressors for the World Market with Compressed Air and Vacuum Technology 2014
New construction and retrofitting of existing plants

Slaughter house waste water:
In addition to improved effluent values and a reduced utilisation of chemicals, users report of significant energy savings following the retrofitting of existing plants. For example by replacing two side-channel pumps by an optimised multiphase pump energy costs of the flotation plant installed in an abattoir have significantly been reduced.

The installed motor power was more than halved. Originally two side-channel pumps each with 7.5 kW motors for an operating point of 9 m3/h against 6.7 bar with 8.3% air contents each were in operation. The aim of these pumps was to separate fat and other contaminations from abattoir waste water that had already been pre-cleaned mechanically (pH value 7). Here the customer complained about an insufficient flotation effect (formation of bubbles) and an insufficient pump service life of two months only.

These pumps have now been replaced by one multiphase pump with a 5.5 kW motor for an operation point of 17 m3/h against 5 bar with approx. 15% air contents. Due to the improved formation of bubbles the effluent results have dramatically been improved. Furthermore the flotate is significantly more compact (Fig. 5). Additionally less flocculants are required. The pump service life instead of formerly 2 months now is prolonged to actually more than three years. The energy balance has also significantly improved (from a total of 2 x 7.5 kW = 15 kW previously to only 5.5 kW now). For 220 working days and a 16 hour operating period per day, this equates to savings of more than 3,500 € per year (at 0.10 € / kWh) on energy costs only. Consequently the retrofitting did amortise after only six weeks.

Municipal waste water treatment:
Since 1929 waste water from the city of Kiel and the connected surrounding communities has been pumped through long sewage outfall...
channels to the Bülk waste water treatment plant where it is treated and finally pumped into the Baltic Sea.

Each year approximately 20 million cubic meters of untreated waste water is pumped to the waste water treatment plant which corresponds to a connected value of approx. 310,000 inhabitants and 65,000 inhabitant equivalents (industrial and commercial).

During a retrofitting in 2011/2012 the downstream flotation that is used to treat the cleaning water of the cloth filters consisting of the conventional system with dispersion pumps, compressors and pressure tanks was modified to the redeveloped system. Four standard pumps were installed as dispersion pumps, each with 15 kW of motor power that feed the pressure tanks with recycling water at approx. 8 bar for air saturation. In order to perform the air saturation of the recycling water a pressure tank, two dissolving tanks and two compressors with 4 kW power were installed.

The dispersion pumps, pressure tanks and compressors were replaced by three of the successful multiphase pumps, each with 5 kW of motor power whereby one of the three pumps serves as a standby pump (Fig. 6). All three components (dispersion pumps, pressure tanks and compressors) were replaced by multiphase pumps during the described retrofitting.

By throttling the pumps down to approx. –0.2 to –0.3 bar artificial vacuum at the suction side, the pumps suck the required air into the pumped liquid. The pumps simultaneously operate as dynamic mixer and, due to the increase of pressure to approx. 8 bar, achieve an excellent solution. This causes a fine-bubble dispersion of the pumped liquid during the pressure release which leads to an excellent flotation result.

By operating in three shift system during assumed 220 working days, the energy savings only amount to more than 100,000 € (at 0.10 € / kWh) annually.

Many municipal waste water treatment systems worldwide have been retrofitting to the new multiphase system (Fig. 7). All users report of similar savings.

**Other projects**

**Limy circulation water in the paper industry:**
In the paper industry calcareous deposits from the circulation water in pipes, cooling systems, heat exchangers, etc. are avoided by the use of lime traps. As a result the freshwater demand is significantly reduced and a sustainable improvement of the process reliability is achieved. The costs associated with repair and maintenance of the systems are also significantly reduced. Originally in a paper factory a partial flow of approx. 288 m³/h was saturated with compressed air in a pressure reactor.
The fed quantity of compressed air was adjusted to approx. 400-500 l/min. For the flotation aeration a standard pump with 75 kW motor power (QN 288 m³/h, HN 6.5 bar, pump power input at QN approx. 68 kW) as well as a 7.5 kW compressor, a pressure reactor for the preparation of the air-water mixtures and a compressed air tank were conventionally installed.

Under the same operating conditions two multiphase pumps each 18.5 kW with air input in front of the pumps were installed. The results indicated a perfect operation of the lime traps at a flow rate of 45 m³/h and a pressure of 4 bar incl. approx. 20 % air as well as a pump power input of approx. 13 kW per pump. A total of 75.5 kW (motor and compressor) was required in the conventional system. In contrast no compressor is required since the multiphase pumps have been used. The pump power input of the two pumps amounts to 26 kW only.

Consequently the total motor power is reduced by 49 kW or remarkable 65.6%. At an energy price of 0.10 € / kWh and an annual operating time of 8,000 hours (three shift system), the annual energy savings amount to approx. 39,600 €. The energy-efficient reconstruction of the plant was amortised after approx. 5 months.

Renewable energy:
In the processing of regenerative energy carriers – such as biofuel, wood, waste fractions with high heat value, or animal meal – the inert CO₂ has to be washed out of the synthetic gas. A compressor forwards the gas into an absorption cell, where it flows ascendingly through a support medium aggregate. This aggregate is being sprayed from above with water that is conveyed by a multiphase pump. During this process the water is enriched with the CO₂ out of the synthesis gas. Afterwards the water is led into a desorption tank, in which most of the CO₂ will outgas. As this water is still saturated for 100 %, gas bubbles occur during priming, that however are soluted again by the multiphase pump – the circuit starts again.

Raw materials production:
It is historically proven that the flotation technology began with the production of raw materials. Most copper mining depends on crude ore
that is cracked, ground in rock crushers and subsequent supplied towards the flotation. Fine air bubbles transport the small mineral particles to the water surface and keep them in the flotate. By means of the water-air mixture and adding of flotation additives at the same time the copper ore is separated from other ores. The ore concentrate subsequently is smelted in the following process.

Ammonia stripping plant:
Downstream the fertilizer production process a stripping system is installed and serves for reducing the ammonia nitrogen content and also the chemical oxygen demand (COD) in the process waste water to the standard values. Initially the waste water is fed into the tank near ground level. From there it is conducted into the multiphase pump where air is aspirated along with the water and brought into solution under pressure. After pressure release the generated water-air mixture is delivered back into the tank through nozzles from above. Due to this sprinkling the ammonia releases gaseous from the waste water. It can be conveyed by a gas pipe to the fertilizer production process again.

Cooling water treatment by ozone:
The innovative conception of the multiphase pumps did lead to participation at seventh frame programme of the EC for research and technological development. Marine bio-fouling is a major problem for materials in constant contact with seawater. Accumulation of marine organisms has impact on the proper functioning of engines and further appliances on board that need constant and proper cooling, and on the safety of the vessels. The project comprises the development of a system for avoiding bio-fouling, by means of ozone improving the quality of the seawater for cooling the ship’s engines and by this avoiding considerable maintenance costs and at the same time assuring a reliable operation of the seagoing vessels.

Crude oil-water separation:
Instead of hydro cyclones the separation of the mixture can also be performed using flotation technology and multiphase pumps. There is generally a significant amount of oil-water mixture when conveying crude oil. Flotation plants equipped with multiphase pumps separate the oil and water. The recovered oil is further processed and the water is sent back to the drill holes. However, in contrast to industrial applications, the multiphase pumps must be designed as super-duplex pumps for resistance reasons. The shaft sealing is executed according to the so-called API plan (API 682 / ISO 21049). Essentially, methane is used in place of ambient air in order to achieve separation.

Supreme process reliability, energy efficiency, the simplification of the plant concept and the associated reduction of plant components that are susceptible to problems and are maintenance-intensive result in a wide acceptance of the innovative multiphase concept.

Result
Supreme process reliability, energy efficiency, the simplification of the plant concept and the associated reduction of plant components that are susceptible to problems and are maintenance-intensive result in a wide acceptance of the innovative multiphase concept. Both the immense savings and the significantly lower running costs compared to the previous plant structure lead to extremely short amortisation times. Even the retrofitting of existing plants paid for itself after a short period of time.

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Rising raw material prices mean that ore and coal mines even in remote and little developed or exploited regions of the world have become profitable. The local infrastructure in those regions is usually not comparable with the infrastructure in Europe. Road and rail connections are usually absent across large parts of the areas in question, which is why pipelines are built alongside rivers, through deserts, mountains, and jungles. The line does not follow the geologically most favorable route but is instead the shortest route to the next harbor or the next processor. This is why it might be favorable to transport the accumulated ore and coal sludge by means of pump units.
Hydraulic transport of sludge can be described as “two-phase flow.” It is a suspension consisting of solid particles mixed with a carrier liquid located in a sealed pipeline. Certain flow rates must be maintained in the pipe in order to pump sludge from A to B; different values apply depending on the consistency of the sludge. Sludge is classified as homogeneous, heterogeneous, and quasi-homogeneous sludge based on the composition, type, and flow behavior.

**Homogeneous sludge:** This type of sludge consists of different phases but flow rates and directions are nearly identical. The reason for this can be found in the properties of the solid particles, the concentration, and the flow rate. The flow profile is symmetrical; the solid particles are distributed evenly.

**Heterogeneous sludge:** This type of sludge consists of different phases, each with different flow rates and directions in the flow. For example, the flow rate must be above the “critical flow rate” to prevent the pipes from becoming blocked. Sediments in the pipes reduce the available cross-section of the pipeline so that flow rate as well as pressure losses increase. The flow profile of heterogeneous sludge is asymmetrical; the solid particles are not distributed evenly.

**Quasi-homogeneous sludge:** At a sufficiently high flow rate, this sludge exhibits the same behavior as heterogeneous sludge.

**Wear/abrasion due to sludge**

All solid materials have a specific hardness — from talcum powder to diamonds. The hardness of any given material contributes significantly to the wear and abrasion of pump components. Similarly, shape and size of the particles is another important factor.

Different types of wear and abrasion (e.g. corrosion, erosion, and/or combination of both) occur in pumps. Correspondingly, various methods are used to determine the type of wear and abrasion behavior. However, a method to predict the actually expected wear behavior accurately does not exist.

One of the most reliable tests is the Miller Number, standardized according to the ASTM Standard G 7582. The Miller Number makes it possible to draw a conclusion about the relative abrasiveness concerning a 27 % chrome steel with a hardness of 62 HRC (hardness test according to Rockwell).

**Examination of wear behavior according to Miller**

<table>
<thead>
<tr>
<th>Sludge Type</th>
<th>Miller Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bauxite sludge</td>
<td>9–400</td>
</tr>
<tr>
<td>Ash sludge</td>
<td>10–120</td>
</tr>
<tr>
<td>Copper sludge</td>
<td>20–120</td>
</tr>
<tr>
<td>Iron ore sludge</td>
<td>25–130</td>
</tr>
<tr>
<td>Coal sludge</td>
<td>6–57</td>
</tr>
<tr>
<td>Kaolin sludge</td>
<td>7–30</td>
</tr>
<tr>
<td>Tailings</td>
<td>24–644</td>
</tr>
</tbody>
</table>
Parameters for the Miller Number are as follows:

- Hardness
- Size
- Form
- Particle distribution
- Brittleness
- Concentration
- Specific weight

The following also have an impact:

- Sludge temperature
- pH value
- Pressure
- Flow rate

**Selecting a suitable pump**

<table>
<thead>
<tr>
<th>Pump type</th>
<th>Miller-Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotary pump</td>
<td>1–50</td>
</tr>
<tr>
<td>Piston pump</td>
<td>50–70</td>
</tr>
<tr>
<td>Piston diaphragm pump</td>
<td>70–higher</td>
</tr>
</tbody>
</table>

**Structure of diaphragm pumps**

The structure of a piston pump for high-pressure sludge transportation follows a classical model. The product valves, pump casings, as well as the pipelines damping mechanisms on the suction and pressure side are primed with the sludge to be pumped. The pipelines must have very thick walls because they are exposed to the pressures as well as the abrasion of the sludge and sediment flowing through the pipe. Flow rates of 2.5 m/s are usually the limit. Such high speeds, coupled with the parameters of hardness, size, shape, particle distribution, brittleness, and the spec. weight of the sludge, generate high abrasion rates in the pipeline.

Diaphragm pumps with high pressures and high outputs are usually connected upstream of slower running booster pumps (e.g. rotary pumps).
A suction flow stabilizer is integrated into the suction side as a dampening element (usually a gas damper). This design prevents cavitation and increases the load degree of the pump.

Thick-walled pipes must also be used on the pressure side (pressure, abrasion). A gas damper is installed in the pressure line as well, connected downstream of the pump. The diaphragms of the damper must be adjusted to the sludge. The gas charge pressure is 0.6 x operating pressure because this setting achieves an optimal dampening. However, to do so, the damper must be properly dimensioned.

### Pulsation dampers

Pulsation dampers are available as:
- non-regulated gas dampers
- regulated diaphragm pulsation dampers

Non-regulated gas dampers are set to a specific operating pressure. This type of damper cannot be regulated and does not work under the preload of the gas charge. To separate product and gas charge, a diaphragm is installed that prevents the gas charge from dissolving, which would require constant refilling. The diaphragm’s pressure is balanced above the preload pressure; below it, the diaphragm moves to the wall of the damper and uses it as a support. The position of the gas damper’s diaphragm (receptacle at the top or bottom) affects the service life of the diaphragm. If the diaphragm receptacle is at the top, the product can become lodged between the diaphragm and the damper wall. The diaphragm constantly rolls over the built-up layer and becomes worn when the spot is so damaged that gas starts to leak. With corrosive fluids, the damper case must also be selected carefully.

Dampens with diaphragm receptacle on the bottom do not have problems with a built-up layer and adjustment to the pumped material to the same extent. The bottom flange and the dia-

![Fig. 3: Diaphragm pulsation dampers](source: Abel)

![Fig. 4: Types of valves](source: Abel)
phrags must be selected carefully to match the product.

Regulated gas dampers adjust to the respective pressure conditions automatically, i.e., non-damped pulsation does not occur. This type of damper is a combination of open pulsation damper and the gas damper.

**Pump valves**

Product valves are dimensioned in such a way that the specific valve load and the valve speeds are as low as possible. This way, the service life of the product valves is extended as much as possible. All valve components can be installed or removed through inspection openings, i.e., the valve boxes do not have to be disassembled to replace wear parts.

The valve seat has a conical receptacle, the valve box a hydraulic connection to press out the valve seat, which is made from through-hardened steel the same as the closing element. Elastomers are used for the seals incorporated into the closing element.

Types of valves:
- Ball valve
- Conical valve
- Mushroom valve

Mushroom valves are a combination of the positive properties of ball and conical valves and offer the following, for example:
- Dynamic behavior
- Easy installation through valve cap opening
- Additional degree of freedom compared with the ball valve

**Characteristics of the pumps**

The product side of the pump must be dimensioned in such a way that the shaped diaphragm, the operating pressure, and the expected wear are considered. The pump case cover must be removable for maintenance without the necessity to disassemble the suction and pressure side tubes. A so-called diaphragm clamping ring is installed behind the pump case cover; this ring or spring presses the diaphragm against the pump case and thus maintains the sealing force so that hydraulic fluid cannot flow into the product, or product into the hydraulic fluid.

The diaphragm is designed in such a way that it will not stretch and/or fold under normal operating conditions. NBR (Acrylonitrile Butadiene Rubber), HNBR (Hydrogenated Nitrile Butadiene rubber), EPDM (Ethylene Propylene Diene Monomer), FKM (Fluororubber) etc. have been proven excellent materials for diaphragms. The outer seal is created with an annular O-ring. Moreover, a metal disk is vulcanized into the center of the diaphragm, which centers and stabilizes the diaphragm. The disk also serves as a holder for the diaphragm rod and protects the hydraulic area from sludge penetration. The metal disk withstands system pressures up to 250 bar so that the diaphragm cannot be destroyed by a defective or improperly closed pressure valve.

The diaphragm is controlled with the diaphragm rod, with the front and rear diaphragm position being monitored. The control is not activated during normal operation so that the diaphragm is able to pulsate freely. The service life of the diaphragm is not reduced by a stress situation. The described measures have yielded a service life of more than 8,000 hours for the diaphragm.

The diaphragm keeps the sludge away from critical and moveable components, which is necessary since these are not coordinated to match
The product (as those parts are that are in contact with the product) but instead originate from a modular system (e.g., cylinder liners, pistons, piston rods, plungers, gland seals).

The hydraulic system contains components to monitor the diaphragm, to discharge the gas, and effect the overpressure protection. Hydraulic oil or emulsion is used as the hydraulic fluid. The reservoir above the control mechanism is a substitute option for any missing hydraulic fluid in case of a leak.

Piston and cylinder lining are designed for heavy duty; the cylinder liner is hard-chrome plated and honed. The piston is equipped with heavy lip seals and piston guide rings. Due to the great positioning forces of the lip seals on the cylinder lining, the piston lubrication must be extensive. The lip seal strips off all deposits on the cylinder wall (including the oil), which leads to the piston (lip seal) running dry. Lubricating the piston spreads the required oil to the rear side of the lip seals and abducts the friction heat as well. This also creates a “water barrier” that prevents air from entering the hydraulic area.

Triplex pumps have an identical displacement volume per piston. Double duplex pumps have different piston front and piston rear side volumes. This is due to the piston rod’s dimensions that must be deducted from the displacement volume of the piston rear side. This unevenness leads to worse residual pulsation values compared to the triplex pump. The additional sealing between piston rod and cylinder is another disadvantage. Since this area is subject to the high operating pressure and must be sealed against air penetrating, packing, lip seals, or combinations of both must be used. The sealed area must also be cooled and lubricated.

The piston rod seal to the pump gears uses bellows or lip seals or packing. The latter two seals must also be cooled and lubricated. This is usually done with gear oil. The bellows is thus the easiest seal.

The demand for pumps with high capacities, great reliability, and long service life has led to the development of hydraulic diaphragm pumps for the transport of abrasive and highly abrasive sludge. These are horizontal piston diaphragm pumps that run slowly due to their long strokes and large pistons. Stroke rates are max. 60/min; some smaller pumps and in special cases with max. 120 strokes per minute are possible as well (2). The max. piston or plunger speed and unbalanced masses (eccentric, eccentric rods), as well as the valve speeds are the decisive factors.

The pumps are either triplex (single-action) or double duplex (double-action) pumps. The two models have different gear designs. Due to the machined allover crankshaft, the triplex gear is able to run at higher rpms; the crankshaft has a crank offset of 120° and because of that a more balanced volume flow. The rigid crankshaft guided by two swivel-joint roller bearings is driven by an external reducing gear. The pistons are pressurized on one side.

Due to the large eccentric, the double duplex gear is unable to run at rpms above 60 strokes per minute; the eccentric offset amounts to 90°;
the piston is pressurized on both sides and exhibits a worse volume flow and higher residual pulsation. The double duplex gear is equipped with an internal gear reduction (herringbone gearing). The herringbone gearing does not generate any forces that have an effect in axial direction and normally must be absorbed by the gearbox. Contrary to a crankshaft, the use of the eccentric shaft makes it possible to install encased main bearings into the eccentric rod. A V-belt intermediate gear is used for capacities up to approx. 200 kW; higher capacities require reducing gears designed to match the capacity. The electric motor is used primarily as a drive motor followed by diesel motors.

Pumps can no longer be started directly because the masses in the pump and the gear are too great. The liquid column in the pipeline must be accelerated slowly if the pump is started when it is connected to a filled pipeline. Bypasses were used for this process in the past. During the start phase, the pump's pressure and suction sides are short-circuited so the pump does not actually pump any liquid or sludge from the pipeline. The bypass is slowly closed once the pump has reached the working rpm; the flushing fluid starts to move slowly until the bypass is closed completely and the required flow rate has been reached. Today, the following devices are used to start the pump:

- Fluid turbo couplings
- Soft starters
- Frequency converters

The pumps available are models HMT (triplex, single-action) and HMQ (double, duplex, double-action). The two models have different gear designs. Piston speeds are below 1 m/s; valve speeds range from 0.8 to 1.8 m/s. This results in very low pump rpms, which significantly reduce wear of the components in contact with the product.

The die line of the gears leads through the main bearings. This type of division makes it possible to fit the large and unwieldy components into
the gear. With at least 1.5 x the stroke length, the lantern is dimensioned generously. It is protected from dust, dirt, and water by an inspection panel.

Splash or centrifugal lubrication can no longer be used with these gears since the pumps reach the necessary operating speeds slowly and are then set back. The pressure circulating lubrication supplies the pump gear with the necessary lubricant. The treated oil flow is adjusted for the individual consumers; oil pressure, oil temperature, and oil pollution are monitored continuously.

These large pump systems can be equipped with a smart monitoring system that indicates the real condition and status of the pump at any time. Regardless of the application location of the pump, the parameters of the pump can be logged on site or at the control station and analyzed by means of remote diagnosis using a modem and/or the Internet.

Application example

At the KCM copper processing facility in Chingola, Zambia, graded copper tailings must be transported from a thickener and cyclone station to a subterranean mine across a distance of 3.5 kilometers where they are used as backfill. Approx. 70 tons of dry solid material must be transported per hour.

A triplex piston diaphragm pump like the one described above was installed for transporting these tailings. The solid concentration in the sludge amounts to 59 %, the sludge volume is 90 m³/h, and the required pressure for the distance of 3.5 km is 50 bar.

The operating costs have been extremely low since the pump has been commissioned: Due to the high efficiency of the new unit, the power consumption amounts to 90 m³/h and 50 bar as well as 160 kW.

The parts replacement is limited to replacing the valves every 5,000 to 7,000 operating hours.

The diaphragms are replaced every 12,000 to 16,000 hours as part of the preventative maintenance.

The piston diaphragm pump used in this case also incurs low operating costs due to the physical separation of the abrasive sludge from the most important moveable parts of the pump using preformed caoutchouc (rubber) diaphragms.

Only the product valves at the suction and pump side as well as the diaphragms are in direct contact with the sludge. The reciprocating principle of the piston diaphragm pump ensures a very high efficiency of at least 93 %. The pump costs of this type of pump are thus minimal and more economic than compared with other methods of sludge removal and transport.

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Literature:
Metering technology for biogases and biofuels

Rainer Sonnenfroh and Walter Richter

Biogas, as a CO₂-neutral energy source, is a future market. The additives used for odorizing or to increase combustion values, however, are just as hazardous as the products that are conveyed during the manufacture of synthetic fuels from biomass. So the pumps used for this purpose must be hermetically tight even under critical process conditions like extreme temperatures and high pressure. Diaphragm metering pumps – especially if the diaphragm consists of multiple layers – have the best characteristics for this purpose, since they can completely eliminate the need for dynamic seals. The pumps work thermodynamically optimally and can be used over a very wide range of temperatures.
The additives to be handed in biogas applications are potentially hazardous according to the applicable EU Hazardous Materials Directive (EC) 1272/2008 (CLP) and EU Chemical Directive 1907/2006 REACH. The hermetic tightness of the pumps used is thus essential. Particularly critical systems include the shaft seals of process pumps and compressors, since their failure not only causes high consequential costs but danger to life and limb. The strict requirements of the Federal Emission Protection Law (BImSchG – section TA-Luft 5.2.6.1 - Pumps) can best be met by the consequent elimination of dynamic seals, for example by the use of leak-free diaphragm pumps.

**Odorization of biogas**

Diaphragm metering pumps for very low flow rates are used among other things for the odorizing of biogas with highly volatile, typical-smelling sulfur compounds such as tetrahydrothiophene (THT) or sulfur-free odorants such as Gasodor S-Free. For the consumer, the addition of an odorant to an odorless gas is an important safety measure, so that leaks or defective systems can quickly be identified during distribution, reloading, or transport.

Since biogas is generally not used for power generation directly on-site, but rather fed into the public gas network or at least transported a few kilometers to the direct consumer (co-generation facility), it must first be refined. The raw gas provided by the farmer consists primarily of methane and carbon dioxide. During preparation, it is purified and the methane gas proportion is increased to about 97 percent. In the initial step, the gas is desulfurized using doped activated carbon filters, rendering it odorless. The carbon dioxide is then removed and the gas odorized with the typical warning odor.

Gas flow controlled diaphragm pumps ensure optimum metering of odorant

In the past, wick odorization, by-pass odorization, or simply adding odorant without control have been used. However, there should be no problems with odor during transport or maintenance work. At the same time, staff should not be endangered at any time. The exact metering of additives is therefore very significant and it is essential to work with absolutely leak-proof systems. Today, odorization must also be monitored in nearly every country, and be carried out proportionally and continuously. In 90 percent of cases, users decide on a flow-controlled diaphragm pump, because these pumps have the best characteristics for quantity-proportional metering of odorant.

A particularly cost-effective solution to meter fluid components in proportion to a variable reference value are hydraulically controlled metering pumps with metal diaphragms and magnetic drives. The different systems in which these are installed use 24 VDC or 230 VAC and are equipped with the core components of pump, flow meter, and controller, along with a stationary container. This container is equipped with a visual level control and can also be used for calibration of the pump. Since at very small stroke frequencies of less than ten pulses per minute there can be a backflow of odorant, an additional solenoid valve is built into the pressure line. This reliably prevents any backflow.
The system is also equipped with an activated carbon filter in the ventilation line, and has a flushing system for cleaning the diaphragm pump head and the suction and pressure lines before maintenance. All the units and components installed must meet the requirements of EC Directive 94/9. All the parts installed are approved for Ex zone 1.

**The smallest dosage is 0.01 milliliters**

Biogas can in principle be odorized at a pressure of up to 100 bar. The DVGW (German Technical and Scientific Association for Gas and Water) G280 regulations specify the exact quantity of odorant to permit even the slightest leak to be perceived. At a throughput of 100 cubic meters per hour, the odorizing additive is mixed in about once a minute. The smallest quantity that can be metered is 0.01 milliliters per pump stroke. The micro flow meter KMM 1 also measures small volume flows at an error range of ± 1 percent, so the odorant is metered safely, proportionally, and economically.

Standard odorizing systems have a modular structure that can be fit together perfectly, with all significant components individually configurable. Depending on the application, not only solenoid driven metering pumps can be used, but also pneumatically or electrically operated metering pumps and well-tested controllers with Internet connections. Only mature, approved components are used that meet international requirements like DVGW G280, WHG, the Pressure Equipment Directive, ISO 9001, GOST-R, ATEX, and TA-Luft. Odorizing systems can also optionally be provided in a stainless steel cabinet with leak pans in various sizes. Lewa also provides overfilling protection, manometers for pressure lines and tanks, and stand-by pumps with automatic switchover.

**Improved process for BTL fuel manufacture**

BTL fuels (Biomass to Liquid) are synthetic fuels made from biomass. The energy revolution has also brought biofuels such as biodiesel and bioethanol into greater focus. Due to climate change and due to the limited quantity of petroleum available and therefore its rising cost, the industrial nations invested in large capacity for first-generation biofuels (for example, biodiesel from rapeseed). Recently, BTL fuels have especially received strong political support in Europe as second-generation biofuels, since their contribution relative to the agricultural acreage required and the resulting transportation power are significantly superior to those of other alternative fuels. In comparison: One liter of BTL fuel corresponds to 0.97 liters of a conventional fuel. For first-generation biodiesel, that value is only 0.9 liters, and the acreage required is more than twice as much.

To obtain biofuel from biomass, there are currently a number of pilot systems in use around the world. The multi-phase processes are generally based on Fischer-Tropsch synthesis, a high-pressure process that was developed in Germany back in 1925 for liquefaction of coal. Diaphragm metering pumps are used at different points in the process, for example as a supply pump conveying the liquid biomass into the high-pressure reactor. Due to the temperatures, some of which are very high (up to +400 °C),
the pumps are often built with a so-called “remote head” design.

**Remote head designs**

The principle of the remote head design is also used for suspensions at high temperature and radioactive, explosive, or toxic fluids in order to keep these critical conditions remote from the displacement system, to protect the facility as well as the surroundings. The compact construction of a normal metering pump makes this impossible.

There are a whole series of structural options that make it possible to separate the valve head spatially from the pump drive. The underlying principle is this: The transmission of the displacement movement is carried out by a liquid column contained in a connection line, the so-called “hydraulic link”. This is set into an oscillating movement by the displacement body that is transmitted to the valve head. The alternating, pressure-controlled opening and closing of the check valve namely forces the pulsating flow of the fluid in only one direction in the valve head. It can therefore work with temperatures from –60 °C to +400 °C.

Depending on the fluid characteristics and the background conditions, the displacement system and valve head can be implemented in either a piston or a diaphragm design. Depending on what pressures and temperatures are reached, it is also possible to locate the valve head geodetically higher or lower than the displacement system. Since the pump drive is located with the displacement system outside the danger zone, a piston design is unproblematic.
Hermetically tight – thanks to sandwich diaphragm

Modern, process-reliable metering pumps are generally built with multi-layer diaphragms (also called sandwich diaphragms). The diaphragm layers are ideally made of pure Teflon (PTFE) and are therefore suitable for nearly any fluid. Especially at extreme temperatures from −30 to +150 °C, the sandwich diaphragm has proved ideal. A service life of over 18 months is normal. The diaphragm, which also works as a static seal, keeps the pump hermetically tight at all times. Dynamic seals, on the other hand, easily become brittle and fail in cold temperatures, which is particularly dangerous for poisonous or highly explosive materials.

The sandwich diaphragm ensures that the pump remains hermetically tight even in the case of damage to one of the diaphragms. The pump can then continue to be operated for a limited time. This is particularly important during the manufacture of fuel, to ensure that the controlled chemical reaction can be completed and none of the highly poisonous or flammable gases in the system, such as hydrochloric acid or hydrocyanic acid, reach the surrounding environment. Monitoring of the diaphragm status therefore takes on greater importance. However, a series of simple, leak-free signaling systems can meet safety requirements at every level. Of course, the materials for the pump, in particular the parts in contact with the fluid, must be selected in such a way that these hazardous materials can be pumped without problems. For this purpose, there are different special materials available, such as hardened or high-strength stainless steels or high-quality nickel alloys like Hastelloy.

Energy of the future

So far, only a few pilot facilities have been built for this type of synthetic fuel production, but even now it can be seen that the process offers a whole series of advantages. For one thing, the entire plant can be used, so that the yield relative to the biomass used is higher than for first-generation fuels. If semi-liquid manure, wood chips, compost, or dairy waste or food waste from restaurants are used, competition with agricultural acreage for food or animal fodder is no longer an issue. The option of decentral co-generation in small production facilities not only reduces dependence on energy imports but also strengthens the regional economy. In the end, BTL fuels are thus also a hopeful option because they can be burned in today’s diesel engines with no modification and can be distributed through the existing filling station network.

The emission values for BTL are lower in comparison with fossil fuels, but there are differences depending on the type of biomass used. The use of waste or forestry byproducts burdens the environment very little. For energy plants, on the other hand, the emission values are higher and fewer greenhouse gases are saved. Another important criterion is conversion efficiency, which depends among other things on whether the process selected can also produce electric power and heat. It will probably take a few years for market readiness to be achieved, but together with the Karlsruhe Research Center,
work is proceeding on further improvements to the manufacturing procedure.

**Strict requirements for injection processes in biogas filling stations**

Most European vehicle manufacturers follow ISO/DIS 15403, which requires a gas quality of at least 96 percent methane content. Since this value is not achieved with biogas, but the oxidizable compound determines how much energy is released in the combustion process, propane or butane is added during tanking to increase the combustion value. Both materials, however, have a negative influence on pinging that must be taken into consideration. To prevent uncontrolled self-ignition, DIN 51626 therefore limits their proportion to a maximum of two to six percent.

To ensure that the additional metering of easily flammable gases results in no danger to the surroundings, the propane/butane is stored underground at normal soil temperatures. During tanking of the vehicle, the metering pump must meter the propane/butane against a pressure of up to 200 bar. Remote head designs can also be used here. However, in this case they aren’t used due to extreme temperature, but to permit the immersion of the pump head in the propane/butane tank, creating the optimum suction conditions for the pump.

Since during tanking of a truck, in comparison with passenger car tanking, the absolute metered additive quantity must be temporarily increased, it is important for the flow regulation range to be very broad with an evenly high efficiency, while the pump continues to run in its optimum operating range. For diaphragm metering pumps, the flow follows the reference value over a very wide adjustment range using the stroke frequency of the drive. The quantity can also be adapted to requirements using an electronically controlled stroke length adjustment.

Each facility operator must meet specific requirements due to different gas qualities. The design parameters for the pumps must therefore always be recalculated from the material data, volumes, and background conditions such as temperature.
**Energy efficiency and low lifetime costs**

Biogas itself may very well be CO₂-neutral, but the energy required over the course of its manufacture, refinement, and transport by pumps can be enormous. The goal is to keep electric drive power as low as possible even for large quantities conveyed. At the same time, the quantity must be accurately and reproducibly specified for metering tasks. In filling stations, a high, flexibly regulated power range must be provided, since the quantity continually fluctuates. Accuracy and adjustability are therefore equally important in order to ensure the energy efficiency of the processes. In particular, rotating pumps, however, can only be designed for multiple working points with great difficulty. Their efficiency is often unsatisfactory under these conditions. Process diaphragm pumps are significantly more flexible in this respect, causing up to 50 percent lower power costs—with correspondingly positive effects on the overall balance sheet of the biogas application in question.

In principle, these high-performance pumps can also be used in industry or for power and heat generation in residential units, hospitals, and schools. Regardless of whether the fuel is transported over several stories or from storage to the vehicle, these applications are continuous processes. The pumps used must therefore be very low maintenance. To ensure this, they are built to prevent dry running and have outstanding safety characteristics even in case of operator error.

Leakage problems in the piston seal in contact with the fluid metered are entirely eliminated: The piston seal and the piston are separated by a diaphragm from the fluid metered, and run without wear in oil in the hydraulic part. This also simplifies their quick replacement if service is needed. The pump heads are entirely sealed inwards and outwards and therefore meet one of the most important requirements for safety and environmental protection. Wear parts must only be replaced after up to 18 months. As a result, there is also a faster return on investment than, for example, for rotating pumps, in which a period of about two years is recommended for amortisation of the purchase costs.

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**Fig. 5:** Draff is a waste product of the process of brewing beer. It can be transferred into a biogas process and used for the manufacture of process heat, which can contribute to reductions in energy costs in the brewery.
Oil and tank farm installations have experienced a real boom over the past few years. New tank farms are being built worldwide to cover the growing demand for crude and refined oil products. And there seems to be no end in sight to this trend. Innovative and more flexible pumping systems can make big contributions to a flexible, smooth and cost-efficient operation of oil and tank farms.
Apart from conventional centrifugal and gear pumps, an increasing number of screw pumps are being used to transport stored oil products. The big advantage is that oil products with various qualities and viscosities, different back pressures and suction conditions such as presence of entrained air or gas can be pumped without difficulties by just one pump. The versatility of the screw pump and its use in low, medium and high-pressure applications up to 100 barg is a huge advantage. Pump speeds of up to 3,500 rpm are acceptable, depending on the individual application. Screw pumps are found in services like

- transfer pumps for different flow rates and pressures
- loading/unloading pumps for tanks / trucks / trains / ships / tank barges
- circulation pumps (tank-to-tank circulation / in-tank circulation)
- tank draining pumps / stripping pumps

The pumping of stored and refined oil products are done by various pump types. Most familiar are double-flow, self-priming, rotating positive-displacement twin-screw pumps, having totally four spindle profiles. These pumps are axially and radially fully balanced so as to avoid the need of special thrust bearings and to guarantee for long service life. The flow is split when entering the pump casing and transferred to each side of the double flow spindle package where it is pressurized to the common discharge. The rotors have to be manufactured from one single piece of material which eliminates the risk of contact between the rotors and casing.

This feature increases the structural integrity and service life of the spindles resulting in a greater operational reliability. If necessary a special modification can be done to the spindle profile, which leads to lower pump noise. The drive spindle torque is transferred to the driven spindle via oil-lubricated timing gears. This ensures an operation of the pump without any contact between the spindles and the replaceable casing insert and the spindle profiles themselves.

An important feature of this type of pump is its ability to pump fluids in the viscosity range from 0.4 cSt to over 10,000 cSt. Furthermore, flow rates of up to 5,000 m³/h can be transported with just one pump. This type of positive-displacement pump also allows for dry running with fluids having low vapor pressure and when emptying tanks or pipelines.

Over the past few years, the focus in pump developments have been on energy consumption, occupational safety and reduction of operating costs for the tank farm owners and operators.
Innovations & trends

Double-acting mechanical seals with a barrier fluid system are also used for applications where longer periods of dry running can be expected.

Innovative, operator friendly and energy efficient pumping systems

Over the past few years, the focus in pump developments have been on energy consumption, occupational safety and reduction of operating costs for the tank farm owners and operators. The self-priming, single-flow positive-displacement pumps with 2 or 5 spindle profiles can also be used to meet the new market requirements. These pumps are designed for a low-pressure operation of up to 16 bar (232 psi) and can transport a wide variety of oil products, from low-viscosity fluids such as „light” gas oil (VGO) to high-viscosity asphalt and bitumen. Fluids with a viscosity of 1 – 100,000 cSt with operating temperatures of up to 280°C can be pumped. The flow rate goes from a few litres per minute up to 1,700 m³/h depending on the pump size selected. One common use of these pumps is the circulation of fluids for mixing and heating of various oil products as well as transfer and loading pumps.

Their design is similar to the more familiar double-flow twin-screw pumps. For example, the casing of these pumps is also in steel with replaceable pump liner and the spindles are made from a single piece to ensure their structural integrity. The pumps are also axially and radially balanced eliminating trust bearings, which guarantees a long service life.

What is special about these pumps is the fact that the idler spindle is not driven by gears. The torque is transmitted hydraulically by the flanks of the drive spindle’s profile. The special profile of the spindle ensures the perfect closure of the pumping chambers so that the fluids are conveyed in an axial direction with no pulsations. This pump design ensures a greater pumping efficiency with reduced power consumption, as result, leading to lower cost of ownership, as pump procurement cost as well is low. It should...
also be pointed to the biggest difference in design to the double-flow twin-screw pump: the mechanical seals to the atmosphere are reduced from four to only one seal. The single-flow positive-displacement pumps have no separately oil-lubricated gears or bearings. This permits the use of single-acting mechanical seals with an oil quench on the atmospheric side of the seal to ensure an oil film is present between the rotating parts of the seal when operating with negative suction pressure. Optionally, a double-acting mechanical seal can be used. This seal should be provided with an external barrier system that is adapted to the pump system and supplies the mechanical seal independently of the pumped fluid.

**Simplified maintenance**

When considering the aspects of maintenance and service, the single-flow pumps are very cost efficient and stand out positively. The following bullet points really hold true for these pumps.

- **Fewer spare parts:** An innovative and parts-saving pump design guarantees simplified stocking of spare parts by the operator or service contractor. The operator can thus calculate the benefits of an optimal stock keeping of parts with a lower service budget and capital tie-up.

- **Simplified service and faster overhaul:** This means in the field service! In the majority of cases, service work can be carried out with less work and with smaller and lighter components directly on site, without the pumps having to be brought to an external shop.

- **Less downtime for servicing (longer running times):** Only pumps that are in operation contribute to the operating company’s profit. Thus, less downtime during servicing have a direct impact on the company’s financial result.

Completely preassembled and tested cartridge units are available to speed service work even more. The operator only has to change the cartridge or the „pump’s entire internals“ at the time of service. The cartridge is simply slid out of the pump casing. A new cartridge can then be slid back into the pump casing and the pump is ready for operation again. The pump does not have to be removed from its base for this work.

The pipe connections on the inlet and outlet side does not have to be removed.

**Advantages over conventional centrifugal pumps**

Tank terminals around the world are getting bigger and bigger and an increasing number of
different oil products are being stored and transported. Striving for the maximum flexibility of facility use, it is the job of the pump manufacturer to implement this flexibility in his pump design. This kind of flexibility is not always possible to achieve with a centrifugal pump. With a typical limited operating window, a centrifugal pump can very quickly run into undesirable operating points, leading to cavitation, vibrations and increased wear or simply stop working. A single-flow or double-flow positive-displacement pump with variable speed control, on the other hand, can cover much wider and demanding conditions of operation. Another advantage is that these pumps are always self-priming. The change of speed results in change of pump flow which can be controlled automatically. No bypass to control flow is required which eliminates loss of energy and overheating (which would be the case with a throttled centrifugal pump). This means that tanks and pipelines can be quickly and efficiently drained and stripped using speed control to lower axial velocities.

With typical centrifugal pumps operating with viscous fluids, the following correction factors related to water data have to be taken into account. Ignoring these correction factors can lead to selecting an incorrect pump size, which will operate outside of its best efficiency point in most cases.

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**Centrifugal pump viscosity correction factors (related to water in %)**

<table>
<thead>
<tr>
<th>Viskosity (cSt)</th>
<th>50</th>
<th>100</th>
<th>160</th>
<th>220</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow reduction</td>
<td>–8</td>
<td>–14</td>
<td>–19</td>
<td>–23</td>
</tr>
<tr>
<td>Head reduction</td>
<td>–5</td>
<td>–11</td>
<td>–14</td>
<td>–18</td>
</tr>
<tr>
<td>Power increase</td>
<td>+20</td>
<td>+30</td>
<td>+50</td>
<td>+65</td>
</tr>
</tbody>
</table>

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**Fig. 5: Pump „suction side view“**

**Fig. 6: Flow chart for the distribution, storage and transport of oil products in tank farms**
It is very important that the vapour pressure and NPSH are taken into account when designing the pumping system. The NPSH available by the facility can be influenced by several factors. In tanks with a floating roof the liquid level can only go down to a certain minimum without endangering the structure of the tank. That is normally the lowest static liquid column or pressure available. The pressure drop from piping, strainers and valves has to be deducted from this value. The vapour pressure and specific weight at a given liquid temperature are further corrections. The pump has to be able to operate under such conditions which is referred to the lowest NPSH available operating point at a given viscosity.

Of these variables, the relationship between vapor pressure and temperature is the biggest element of uncertainty. Screw pumps, and in particular single-flow positive-displacement pumps are designed to operate with very low NPSH available. The risk of cavitation, vibration and vapor locking is greatly reduced and the operator can fully exploit the inherent properties of these pumps to his advantage.

Application examples

**Loading and unloading:**
In tank terminals for ship loading, large volumes of oil products must be transferred in the shortest possible time. The pumps have to be able to operate quickly and reliably. That is also the case in bunker stations or bunker ships or barges. The single-flow screw pump is ideal for this service. It can be installed vertically in the tank or on deck to save space. The flow rate is practically independent of backpressure and the transfer rate can easily be controlled by adjusting the pump speed, protecting the receiving tank from overfilling.

**Circulation and blending:**
Screw pumps are also used to mix oil products with different viscosities in tank farms. A continuous, pressure-independent pumping rate using speed control is the guarantee to achieve predetermined blending ratios. This can be used particularly for heavy oils blending with light NAFTA or other light hydrocarbons to produce a desired commercial quality.

An increased production of very heavy crude oils, bitumen, asphalt, carbon black, pitch etc. is being supplied to the global market. Purposely built tank terminals and pump stations are required for trading these products. Centrifugal pumps cannot be used in these applications due to poor efficiencies with high viscosities and unpredictable operation characteristics. The speed-controlled, single-flow screw pump as well as the double-flow, positive-displacement twin-screw pump are the reliable alternatives.

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Intelligent design for hygienic pumps: from barrel emptying systems to dosing

Rainer Gozzer

EHEDG, QHD and FDA make exact demands on machines for the food and pharmaceutical area. These not only involve production facilities themselves, but also all conveying systems which come into contact with the medium. So as to make the progressing cavity pump fit for this area of application and to bring it into compliance with the strict regulations, numerous changes have been made to the proven design, including materials, construction and seals. The hygienic pumps which emerged from this process have now come into use not only purely for transporting materials, but also to take on emptying and dosing tasks.
Hygiene and processing requirements in the food and pharmaceutical sector are increasing all over the world. Many things that were previously standard practice have now become outdated in terms of the safety of consumers and are no longer permitted. There are also ever more sensitive media which have to be mixed together and processed. For manufacturing industries, this also means increasing demands on their conveying systems, which had until now often been given little attention in comparison with the production facilities. At the same time, maintenance expenditure and service life are nowadays crucial factors in terms of a company’s commercial efficiency, considering global competitive pressure. In order to be able to tackle all three issues – hygiene, material sensitivity and efficiency – pumps have now been developed with intelligent component design that corresponds to various task profiles, for example both in insulin synthesis and in fruit juice production.

Progressing cavity technology is gaining ground

After a long period when centrifugal and diaphragm pumps had controlled the market for conveying foodstuffs and other critical substances, for some years now progressing cavity technology has also become increasingly established in this area. The main reason for this is particularly smooth transport, which can be attributed to the special operating principle of the progressing cavity pump. A helix rotor rotates within a flexible, reverse-helix stator which is geometrically adapted to it. Identically shaped conveying chambers are formed between the two components.

As the rotor turns, it continuously conveys the medium from the inlet to the discharge side. The chambers are closed off by a sealing line which is effective along the full length of the rotor-stator combination. As a result, there is hardly any backflow and no valves are needed to limit the chambers.

The precise matching of the two components to one another enables conveying chambers to open on the inlet side between the stator and rotor and then to move to the discharge side with the rotation. When these are being filled with the media, the conically shaped stator aperture ensures consistent and complete filling of the conveying chambers. If the uptake of material proves to be difficult in the area of the stator inlet, for example due to high viscosity or lumpiness of the conveyor medium, the coupling rod upstream from the rotor can be fitted with conveying screws as a support measure.

In addition, the rotor-stator geometry can be selected to correspond to the relevant application. The S-geometry is therefore suited to a large inlet cross-section and low flow speeds for compacted products or those with a proportion of coarse solids. On the other hand, the L-geometry is characterised by a pitch twice as long and thus by a significantly higher capacity. Because the size of the transport chambers always remains the same, use of this technology means the medium is conveyed continuously and in stable volumes. There is no pressure fluctuation or backflow which could have a negative impact on the medium and there is hardly any occurrence of pulsation or shear forces either.

For some years now, progressing cavity technology has become increasingly established in the market for conveying foodstuffs and other critical substances.

Fig. 1: Progressing cavity technology is characterised by particularly smooth conveyance. In order to be able to use this in food and pharmaceutical sectors, the pumps have now been tailored to their hygiene requirements.
Conveying sensitive substances under difficult conditions

One example of this feature being used is with a chocolate producer in Norway. The intention there is to convey 25 to 40 litres of egg white per hour at a back pressure of 4 to 6 bar. Of the two types of geared pumps which were used on a trial basis, one triggered the curdling of the egg white due to the friction heat on the shafts. This made it unusable for processing. With the other model, this was in fact prevented by special shaft seals, but the pump could not build up enough pressure due to backflow. A piston pump was also unsuitable due to it being oversized and to the combination of low capacity, high conveying pressure and low viscosity. In contrast, progressing cavity technology with its sealed conveying chambers enabled constant throughput rates without any unwanted alterations to the medium, even with 11 bar back pressure.

A similar picture also emerged with biotechnological insulin analogue production. There is an ever growing need for these analogues due to the increasing number of diabetic illnesses, but the plate filters used in the synthesis process present a problem for some types of pump, because they are subject to varying differential pressures depending on the filling level. A high level of stability in terms of quantities is extremely difficult to achieve with these fluctuations without a uniform conveying principle that is not dependent on pressure. However, it is particularly important for the bacterial and yeast cells with recombinant DNA used in the process to be transported to the various processing stations with great care. Mechanical stresses, for example shear forces, could slightly damage the cell walls of the cultures or even destroy them, which would make the cell mass worthless in terms of further production. The smoothest possible conveyance is therefore essential, as with many other modern pharmaceutical applications too, and this has led to one of the largest hormone manufacturers now using progressing cavity pumps to feed filters and to transport cultures.

Optimum cleanability by avoiding dead spaces

However, in order to be approved at all for these kinds of critical areas, pumps are subject to a whole series of hygiene directives, from EHEDG via the 3-A Sanitary Standard through to the requirements of the US Food and Drug Administration (FDA) and the German Federal Institute for Risk Assessment (BfR). The food compatibility of the installed materials and the cleanability of the design lie at the heart of all these regulations. The progressing cavity pump has therefore been appropriately adapted for uses in hygienically sensitive areas. A modified mechanical seal housing therefore results in a huge improvement in terms of cleaning efficiency in the area of the seal and means the pump has no dead spaces. In addition, attention has been paid here to a design which optimises flow, so as to prevent any conveyor medium remaining in
this area during the production phase. For the same reason, all surfaces that come into contact with the medium are also electropolished and, when required, achieve an average roughness of under 0.8 microns. Even for the shaft sealing a special seal version with encapsulated wave spring and a completely smooth, seamless outer contour is used if necessary, instead of conventional seals with elastomer bellows and exposed wave spring, and this enables viscous or adhesive substances to slide off easily as well. The most suitable solution where maximum safety is required is the use of closed double seals which can be exposed to sterile condensate or detector fluid, so that any possible leaks can be seen straight away.

The pin joints on the end of the coupling rod, which transfers the torque from the drive to the rotor, are a typical additional challenge in most cases. To prevent deposits here, an open joint design has been developed in-house which has few seams and dead spaces and is rinsed by the medium from all sides. This means the surfaces are not only constantly rinsed during the conveying process, but need no external lubricant either, thanks to lubrication via the conveyed medium. Furthermore, the head of the coupling rod is provided with two flushing holes which not only improve the lubrication of the joint, but also the efficiency when cleaning. That is because this hole optimises the circulation of the cleaning solution in the area of the articulated joint. The joint pin itself is made a little over long, so that the articulated joint is even more accessible for both the medium, which improves lubrication, and also for the cleaning solution, which enables more thorough rinsing.

A flexible rod is offered as an alternative for non-lubricating or abrasive media, where open articulated joints are not possible, or for more exacting demands right up to the aseptic area. This is heat-shrunk with the rotor and connection point and therefore hermetically sealed. It also includes no other parts which move against one another, apart from the joint, which means it can work without lubrication or seals in a wear and maintenance-free way. Even the highest ambient temperatures and pressures do not affect its functionality. Both the pin and hygiene joint meet the requirements of the 3-A Sanitary Standard.

Cleaning is however not only an important factor for the joints, but also for the pump as a whole. The systems are subjected to the CIP (Cleaning in Place) or SIP (Sterilisation in Place) processes for hygienic or aseptic cleaning. In order to achieve the cleaning fluid flow speed of

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At least 1.5 m/s required through the whole system during the CIP process, the progressing cavity pumps are also fitted with additional tangentially arranged cleaning ports and equipped with a bypass line. In the context of reworking the design, the vertical inlet ports on the pump housing have also been positioned tangentially for technical flow optimisation, which means it has been possible to achieve a huge increase in cleaning efficiency. The cleaning port also enables complete emptying of the system. This is because its tangential position prevents any rinsing water remaining in the pump housing after cleaning has finished. The eccentrically positioned end connection on the stator side also contributes to this. This design means the rinsing water can flow out of the pump housing unhindered, without leaving any residue.

It is not just a case of the pump materials needing to be tailored to the conveyed medium, the cleaning temperatures and cleaning solutions which are needed, depending on the application, have to be taken into account in the choice of materials as well. The example of insulin synthesis, where diluted sodium hydroxide and phosphoric acid are used for flushing in addition to deionised water, shows how high the material stress can be here. Stainless steel components and particularly robust elastomers have been fitted, which nevertheless comply with the FDA directives. This choice has enabled service lives to be achieved which, in spite of the aggressive cleaning, are still above the originally estimated replacement intervals of one stator and one and a half rotors per year and pump. In fact, it has been demonstrated that the stators can run for around five years, and the rotors even for ten years, without any significant signs of wear.

Versatile applications for the hygienic pump

The special conveying technology of hygienic pumps makes them suitable for a wide range of different media, from shear-sensitive, adhesive or highly abrasive materials to low and high-viscosity materials. The pump housing and stator can also be provided with a heating or cooling jacket, if this is necessary for the flow characteristics or to protect the medium for technical processing reasons. To prevent damage to the stator due to dry running, there are in addition optional stator protectors which use one or two thermal sensors to register rising friction heat in good time when there is unauthorised operation without any medium, and switch the system off. Depending on the space available and requirements for incorporation into the production process, the pump is made in a block design with a flange-mounted motor or with a bearing housing. It is manufactured and tested in accordance with both EHEDG and QHD directives and fulfils the international requirements of the American 3-A Sanitary Standard as well as the Russian GOST-R. All materials are approved according to FDA specifications.

Because hygienic pumps can be used vertically as well as horizontally and can also provide suction through to the creation of a vacuum, you can also use the model in designing a barrel emptying system for foods and other sensitive substances. Barrels, particularly those with a low viscosity content, are usually clamped in a tilting unit and emptied into the conveying system or a collector tank via a hopper. The fastening and pivoting of the barrels, which are often heavy, involve a certain amount of effort, but above all it is impossible to guarantee that the product is free of contamination during this open decanting process. Air pockets, dust and even insects can easily get into the medium.
Contamination and almost residue-free barrel emptying

In order to avoid this and to ensure extensive usage of all the medium deployed, the hygienic barrel emptying system works with a follow plate made of polished stainless steel. This is selected according to the size of the barrel and is surrounded by a joint seal made of FDA-compliant elastomer, which means it seals the barrel during the discharge process and prevents the ingress of impurities. The plate is fitted to the inlet ports of a vertically installed hygienic pump and this creates a vacuum in the container after it is switched on. As a result of the vacuum generated, the design automatically provides suction towards the bottom of the barrel, whereby the follow plate sits on the medium and this prevents any air pockets. At the same time, the medium is gently pushed into the inlet port to ensure continuous emptying. The content is almost completely discharged using this method, with a residue amounting merely to around one percent remaining in the barrel. The sealed follow plate, used as a protection against contamination, also improves the usability of the product deployed and reduces the effort involved in cleaning the barrels. In particular, the wall is already pre-cleaned thanks to the flexible levelling collar.

The apparatus itself – like the pump – can also be quickly cleaned, because the design is kept very lean overall, and only a very small number of individual parts are fitted. The outer components can easily be removed for cleaning, as they are fixed on with connecting clamps. Thanks to the compact design, the emptying system is also suitable for mobile use and can easily be transported to the relevant application site on rollers. The systems can be controlled using various input methods, from the classic start-stop switch to the modern touch panel, which clearly shows all the device parameters as well as the control functions. Even integration into an automated processing line is possible. The barrel emptying system’s special sensor technology comes into play here: sensors on the pneumatic cylinders recognise when the fill level is approaching zero and interrupt the suction before dry running can occur. Twin systems, each for two containers, also use this monitoring option to minimise the interruption of conveyance as a result of changing barrels. As soon as the sensors report the emptying of one barrel, suction automatically switches to the second, while the first is changed.

Fast processing of larger barrels too

Users of this technology include a Swedish producer of bakery products which procures fruit jelly in barrels to decorate cakes and similar items. So that it has the required malleable consistency suitable for spraying, the mass must be pressed through a filter using a special machine. Until now this had been filled by hand, with workers pouring the heavy 20-litre buckets into the device manually. The hygienic barrel emptying system means this effort is no longer needed, as the fruit purée is cleanly transported to the system via a pipe. In addition, the company can in future procure the raw material in more efficient 200-litre drums, which it would
have been impossible to handle with the old process, instead of in small 20-litre barrels. In order to make the switch easier, the emptying equipment was provided with an adapter, which both sizes of follow plates can fit onto.

Another application is fruit juice filling. This traditionally works with expensive tipping systems, which do not completely empty the barrels either and thus make it necessary to carry out time-consuming subsequent cleaning.

A manufacturer with these types of filling lines has therefore switched their products to suction via progressing cavity technology and integrated a system which achieves a throughput rate of 11.6 cubic metres per hour with a pressure of up to twelve bar. The emptied containers can be replaced easily and quickly by full ones via a roller conveyor, so that users can empty an average of one barrel a minute with it. Barrel emptying systems are generally suitable for containers from 0.5 to 200 litres, with special customised models having also been developed for up to 1,000 litres. The standard range of possible conveyance rates goes from six millilitres a minute to ten cubic metres an hour.

**Dosing proportional to speed**

An additional advantage of emptying using the progressing cavity principle is that you can dose directly from the barrel. The reason for this is conveyance between rotor and stator in identically shaped chambers, which means the quantity of the transported packages of medium is only dependent on speed and can be continuously adjusted using this. The maximum dosing accuracy of barrel emptying systems is therefore between three and five percent. For even higher levels of accuracy, you can connect more progressing cavity pumps with smaller chamber volumes right through to dispensers, which achieve a volumetric accuracy of one percent from 90 degree rotor rotation – but also only convey a half to ten millilitres per revolution. With these models, a universally adjustable retraction system prevents any falsification of the quantity through subsequent dripping.

Dosing proportional to speed for instance helps with the production of mayonnaise, as the addition of oil must at all times be precisely adjusted to the existing oil-water ratio in this process. Even the smallest errors in composition would otherwise make the sensitive emulsion unstable. Very precisely measured doses of oil are therefore transported to the mixing container using a progressing cavity pump.

Fig. 6: The plate provides airtight sealing of the barrel and prevents contamination. At the same time, the pump automatically moves downwards due to the vacuum generated during the emptying process.

Fig. 7: Where robustness or high pumping capacity is required in a limited space, the hygienic version of the rotary lobe pump represents a sensible alternative to the progressing cavity pump.
Hygienic rotary lobe pump for special requirements

In very confined spaces, the long form of the progressing cavity pump does however have its limitations. Another displacement pump with a more compact design, the rotary lobe pump, is offered as an alternative and there are also hygienic versions of this available. These are also suitable for a multitude of different materials, including shear-sensitive, thixotropic and high-viscosity types. They work reliably over a wide range of temperatures in this area and achieve throughput rates of up to 150 cubic metres an hour. As a rule, tri-lobe or four-lobe rotors are fitted here, so as to keep unwanted pulsation effects to the minimum possible level and to protect the medium. Nevertheless, the free ball passage between the rotary lobes, which rotate in opposite directions, is wide enough for larger objects, such as pieces of fruit for example, to pass through undamaged and without any risk of clogging. The shaped intake aperture improves the flow of the product as it comes into the pump chamber, and an inlet with an enlarged cross-section can also be used if required for high-viscosity media.

The compact design of the rotary lobe pump means it fits into small spaces and can easily be taken from one application to another as a mobile model on a hand trolley or its own chassis. In addition, importance was attached to a high level of robustness in the design. The gear box housing is therefore made of grey cast iron and the shafts are carried by tapered roller bearings which have a high concentricity tolerance and can withstand severe stress. A timing gear is used to synchronise the rotary lobes and its helical gearing guarantees optimum positioning of the rotary lobes with respect to one another, and so ensures low-noise, low-friction and low-vibration operation. The physical separation of the pump chamber and gear box excludes a complete write-off of the system due to leakage.

To make cleaning easier, the housing cover can be removed, which then means that the rotary lobes and shaft seals are easily accessible. Even replacement is easy to carry out, because neither the housing nor the pipes need to be disassembled to do this. Single mechanical seals which are not dependent on the direction of rotation are normally used as shaft seals, but double-acting mechanical seals can also be used in different versions. The housing port is attached directly on top without any dead spaces, which means deposits during conveyance are avoided. For residue-free self-emptying, the installation direction of the pump can be turned through 90 degrees, so that the connections are positioned vertically above one another. In general, the hygienic rotary lobe pump is designed for CIP and SIP processes in terms of construction and materials and it can even be used itself to generate the cleaning fluid flow speeds required for these, thus being able to act as both a conveying pump and a cleaning pump.

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The sixth edition of “Pumps and Compressors for the World Market” in 2014 strikes a new course: Together with the magazine you hold in your hands, if you go to [www.vdmashop.de/puco](http://www.vdmashop.de/puco), you will find our first E-Magazine with additional features. The heading “Products & Applications” provides a user-oriented look at the latest technical developments, trends and products in the respective branches – as a brief summary in the printed version and in greater detail in the E-Magazine with in-depth information about the respective topics. The flags indicate the languages in which the articles are available.

**KSB Aktiengesellschaft:**
**New zero-leakage refinery pump**
In early September 2013, KSB Aktiengesellschaft, Frankenthal, Germany, launched a zero-leakage mag-drive pump series in back-pull out design: RPHmdp. The horizontal, radially split volute casing pump to US standard API 685 has been developed to reduce maintenance costs and ensure a maximum service life.

[www.ksb.com](http://www.ksb.com)

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Sterling SIHI GmbH: Online condition monitoring
Considering the life cycle cost of pumps, it becomes obvious, that cost for maintenance and repair – beside energy cost – are offering the biggest potential for savings. Hence it should be aimed to reduce the repair and maintenance cost and in addition to avoid cost for production downtime by utilisation of efficient and intelligent condition monitoring systems.

www.sterlingSIHI.com

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## Applications

### Pumps & Systems

<table>
<thead>
<tr>
<th>Company</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABEL GmbH &amp; Co. KG</td>
<td>Water supply/wastewater disposal, Construction irrigation, Well drainage,</td>
</tr>
<tr>
<td>Alltech Dosieranlagen GmbH</td>
<td>Drainage, Groundwater conservation/lowering, Cellar drainage, Sewage treatment</td>
</tr>
<tr>
<td>ALLWEILER AG</td>
<td>Agriculture, Seawater desalination, Drainage, irrigation, lifting stations</td>
</tr>
<tr>
<td>ANDRITZ Ritz GmbH</td>
<td>Swimming pool technology, Overhead irrigation, Sewage treatment plant, Drainage,</td>
</tr>
<tr>
<td>Apollo Gößnitz GmbH</td>
<td>Irrigation, Well drainage, Swimming pool technology, Overhead irrigation,</td>
</tr>
<tr>
<td>Beinlich Pumpen GmbH</td>
<td>Sewage treatment, Hygiene/cleanliness, Biochemistry, Brewery, Dosing technology</td>
</tr>
<tr>
<td>bielomatik Leuze GmbH + Co. KG</td>
<td>Injection, Pharmaceutical industry, Sample taking, Sterile technology,</td>
</tr>
<tr>
<td>ITT Bornemann GmbH</td>
<td>Industry-/chemical industry processes, Tank, container, barrel, Chemical</td>
</tr>
<tr>
<td>Brinkmann Pumpen K.H. Brinkmann GmbH &amp; Co. KG</td>
<td>industry Draining, Gas dehydration, Gas washer, Industrial technology,</td>
</tr>
<tr>
<td>Paul Bungartz GmbH &amp; Co. KG</td>
<td>Surface treatment, Steel construction and vehicle construction industries,</td>
</tr>
<tr>
<td>CP Pumpen AG</td>
<td>Stone, earth and glass industries, Storage tank installation, Textile industry</td>
</tr>
<tr>
<td>Crane Process Flow Technologies GmbH</td>
<td>Building applications; heating and cooling, Pressure boosting, Fire-fighting</td>
</tr>
<tr>
<td>DELIMON GmbH</td>
<td>system, Building controls and systems, Heating technology, Refrigeration</td>
</tr>
<tr>
<td>Deutsche Vortex GmbH &amp; Co. KG</td>
<td>and air-conditioning engineering, Heat-transfer technology, Energy generation</td>
</tr>
<tr>
<td>DIA Pumpen GmbH</td>
<td>, Energy engineering, District heating, Firing technology, Geothermics,</td>
</tr>
<tr>
<td>Dickow Pumpen KG</td>
<td>Prime movers, Power station technology, Flue gas purification, Petrochemical</td>
</tr>
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<td>Düchting Pumpen Maschinenfabrik GmbH &amp; Co. KG</td>
<td>; Oil and petrochemical industry, Off-shore technology, Mining; Metallurgy</td>
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<td>EDUR-Pumpenfabrik Eduard Redlien GmbH &amp; Co. KG</td>
<td>and rolling technology, Mining, Iron and steel industry, Rolling-mills,</td>
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<td>FELUWA Pumpen GmbH</td>
<td>Chemical engineering/Process technology, Process engineering, Sugar industry</td>
</tr>
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<td>Mining; Metallurgy and rolling technology, Mining, Iron and steel industry,</td>
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<tr>
<td>Gather Industrie GmbH</td>
<td>Rolling-mills, Chemical engineering/Process technology, Process engineering,</td>
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</tbody>
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**Note:** The table above lists the applications for various pumps and systems. The company names are linked to their respective websites.
<table>
<thead>
<tr>
<th>Applications</th>
<th>Chemical industry processes</th>
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<tr>
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#### Pumps & Systems

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**GEA Tuchenhagen GmbH**  
www.tuchenhagen.de

**GEA Wiegand GmbH**  
www.gea-wiegand.de

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**Körting Hannover AG**  
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**KSB Aktiengesellschaft**  
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www.leistritz.com

**LEWA GmbH**  
www.lewa.de

**Lincoln GmbH — Lincoln is an SKF Group Brand**  
www.lincolnnindustrial.de
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Mahr Metering Systems GmbH
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### Pumps & Systems

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Radial turbines for energy generation from geothermal resources or waste heat recovery

Prof. Dr. Pall Valdimarsson and Dipl.-Ing. Markus Sauerborn

The implementation of sustainable solutions is becoming a major focus of mechanical engineering. This emerging trend is also reflected in the growing number of geothermal power plants. From a market perspective, we are seeing a major push towards geothermal resources with low enthalpy. The key technology for unlocking these power sources is the Organic Ranking Cycle (ORC), a process in which turboexpanders generate electricity from working fluids other than water vapour. In terms of engineering, ORC-based processes rely on turboexpanders with a radial turbine design.
Geothermal energy – renewable energy source with future potential

Heat from geothermal resources is considered a renewable and clean energy source. The world’s first geothermal power plant was built in 1913 in the Tuscan town of Lardarello, Italy. Today, installed capacity of global geothermal energy generation has grown to 11 GW. Major drivers behind the exploration of geothermal energy generation are measures to halt climate change and related efforts towards the reduction of greenhouse gases. Since high-enthalpy geothermal resources in close proximity to metropolitan areas are, for the most part, already being leveraged for energy production, the market is increasingly focused on low-enthalpy resources. Faced with rising market prices for renewable energies, companies are willing to make larger, more targeted investments, mobilizing larger technology budgets in the process.

Organic Rankine Cycle – unlocking geothermal resources with low enthalpy

One of the key technologies behind the growth of the geothermal energy market is the Organic Rankine Cycle (ORC). This thermodynamic process allows for generating electricity from heat sources, in which the temperature gradient between heat source and heat sink is too low for powering a traditional condensing steam turbine. However, using ORC technology as an alternative also requires higher investments. The current installed base of ORC-driven power

When it comes to energy production from geothermal heat sources, the market is increasingly focused on low-enthalpy resources.

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The ORC process – choosing the alternative working fluid

Technically speaking, the ORC process is based on a steam power cycle according to Clausius-Rankine. But instead of water, the ORC relies on organic working fluids chosen in accordance to the temperature conditions at the respective geothermal heat source. Another major factor for selecting the working fluid is its sustainability. For instance, operating a geothermal power plant in densely populated areas with high electricity costs calls for a non-flammable, rather costly working fluid. In regions with low population density and lower costs of electricity, a less costly working fluid presents a more economical choice. Low-cost options include hydrocarbons such as those used in cigarette lighters. But since carbon hydrides are highly flammable, their usage in power plants is subject to strict safety guidelines, on par with those applicable to petrol stations.

Overall, the selection of the working fluid should match the thermodynamic properties of the heat source, as well as the geographical location of the power plant.

The ORC process for geothermal applications

In an ideal geothermal power plant process (Fig. 1), heat is applied to the working fluid inside the preheater and evaporator. Due to the sub-cooled condition of the working fluid upon exiting the condenser and the rise in pressure in the working fluid pump, the working fluid temperature will initially rise until reaching the boiling point (sensible heat). During vaporization, the supply of heat continues, while the working fluid temperature remains stable (latent heat during phase transition). After the rest of the liquid is evaporated, the temperature of the working fluid rises once again.

During the process design stages, the ratio of sensible to latent heat can be adjusted to conditions at the heat source: The closer the boiling pressure of the working fluid is to its critical pressure, the smaller the share of latent heat. Pre-evaluation of the heat source calls for a number of observations. In case the heat source is available in liquid state only, its temperature will fall due to heat extraction in the pre-heater and evaporator. But, if the heat source is also partially supplying vapour or non-condensable gases, both the cycle and the working fluid need to be geared towards a larger share of latent heat.

The ORC process for waste heat recovery applications

Energy generation from waste heat – also known as waste heat recovery – with an ORC process is similar to the design of geothermal power plants. Practical applications include waste heat from gas turbines or incineration engines, as well as processes during which heat
is released as a waste product, e.g. cement manufacturing. Due to the comparatively high temperature levels at the heat source, heat transfer from the source passes through a conducting medium, for instance a heat transfer oil that passes on the heat to the ORC process (Fig.2). Also due to the high level of heat at the source, power generation from waste heat is also suitable for so-called trans-critical ORC processes. In these processes, the high pressure side exceeds the critical pressure of the working fluid. During heat transfer, the working fluid does not undergo a phase change by means of condensation, but a continuous change in density instead.

Radial expansion turbines – perfectly suited for ORC processes

Both the geothermal and waste heat recovery ORC process rely on radial expansion turbines. While an expansion turbine, also called a turbocompressor, hardly differs in terms of its basic design from a turbocompressor, the main difference lies in the direction of power transfer: In a compressor, power is transferred from the drive shaft to the flow (turbo working machine), while in an expansion turbine, power is transferred from the flow to the blade row (turbo power machine).

The Euler turbine equation relates the power transferred between the flow and blade row by means of angular velocity, direction change of fluids’ tangential velocity and the geometry of the turbine.

\[
P = \tau \cdot \omega = m \cdot (u_{in} \cdot f_{in} - u_{out} \cdot f_{out}) \cdot \omega
\]

where:

- \( P \): Power transferred
- \( \tau \): Torque
- \( u_{in} \): Inlet tangential velocity
- \( f_{in} \): Inlet flow radius
- \( u_{out} \): Outlet tangential velocity
- \( f_{out} \): Outlet flow radius
- \( \omega \): Angular velocity
- \( m \): Mass flow

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The amount of power transferred is determined by the tangential velocity and flow radius at the inlet and outlet of the turbine. Flow capacity at turbine inlet is limited by the speed of sound. In order to optimise performance, the inlet radius should be designed at a larger size than the outlet radius.

Turbines with radial inflow design – the perfect choice for ORC applications

The radial turbine can be adjusted by means of variable Inlet Guide Vanes (IGV). By adjusting the guide vanes, or "nozzles", the flow cross-section, or "gap", as well as the angular velocity at the guide vane can be modified. This ensures that the angle of attack of the flow on the leading edge of the rotor blade is kept correct, even if the flow changes (for instance, minimum incidence angle). The turbine rotational speed can be used as a constant controlled variable. Thereby, the performance curve of a generator-braked radial turbine in terms of a constant isentropic efficiency and rotational speed across the entire performance map can be considered optimal. The efficiency performance curve only decreases slightly under off-design conditions. Therefore, radial turbine design is an excellent match for the requirements of an ORC-based power plant.

The technology is also perfectly suited for climate zones with considerable seasonal variations in ambient temperature, leading to deviations in condensing pressure in facilities where air-cooled condensers are used. Another usage scenario includes block heat and power plants with combined heat and power (CHP) generation, in which the amount of heat used to generate electricity is reduced during the cold season in favour of direct injection into the district heating grid.

Overall, a stable performance curve is beneficial for all applications, in which the process is run under off-design conditions as well as processes, in which off-design conditions differ significantly from initial operating conditions.

Advantages of radial turbines compared to axial or impulse turbines in ORC-based waste heat recovery processes

As opposed to the radial turbo expander design described above, an axial turbine can only be controlled by means of a throttling valve at the machine inlet. When the flow is changed from the design volume flow, then the angle of attack at the blade leading edge will change, which leads to reduced efficiency. This also directly leads to a decrease in efficiency. As a countermeasure, tolerances towards angle of attack changes in axial turbines can be increased by modifying the profile of the rotor blade, e.g. by increasing the radius at the blade leading edge. But this also leads to diminished aerodynamic efficiency of the entire stage.

Under these conditions, the impulse turbine design is also inferior to radial turbines with var-
Radial turbines support higher pressure ratios and broader areas of applications

Due to their design, radial turbines can achieve much higher pressure ratios per stage than axial turbines. In practice, pressure ratios up to 10 are common for single-stage radial expanders. In order to achieve the same pressure ratio, an axial design turbine would require three to four stages. Additionally, radial turbines are suited for much higher maximum temperatures at the inlet – up to 300°C.

These performance features make radial turbines first choice for ORC-based, trans-critical waste heat recovery applications with their high temperature levels and exclusively sensible heat transfer processes.

Integral design for several turbines on one drive

In cases where a process requires more than one turbine stage, these can be mounted on a single gearbox. This integral design approach, also commonly used in multi-stage radial compressors, can be suited towards individual customer and process requirements. For an example, please see Fig. 4. The turbine shaft serves the function of a pinion shaft of the gearbox, thereby increasing the compactness and sturdiness of the design. This is especially suited as a cost-efficient solution in ORC-based power plant applications where a single turbine alone cannot transfer the entire power provided by the process. The same applies to processes with multiple pressure levels.

Advantages of gas-lubricated mechanical face seals – optimal turbine efficiency

For the gas-side shaft seal in radial turbines for ORC applications, gas- and oil-lubricated mechanical face seals are both viable alternatives. Both designs offer minimal leakage and smallest possible overhang of the turbine rotor, thereby facilitating an optimal degree of rotor dynamics. Gas-lubricated mechanical face seals (or dry face seals) rely on inert sealing gas to prevent the already minimal leakage of process gas to be released into the envi-
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Environment. Together with the appropriate process configuration, this also helps to prevent contamination of the working fluid with inert gas.

However, in this process the rest leakage of the working fluid mixes with the flow of sealing gas. This requires an additional step in the process to separate both gases in a seal gas recovery unit. Afterwards, the leaked process gas is reinserted into the ORC process. The elimination of working fluid leakages is not only a priority from a plant operator’s perspective, but the process gases, e.g. refrigerants, are costly materials that also add to the emission of greenhouse gases. This is in sharp contrast to the underlying promise of sustainability achieved through geothermal power generation.

The advantages of dry face seals include maximum rotational speeds for optimal turbine efficiency. Their main disadvantage, especially when it comes to ORC-based applications, lies in the requirement for cost-intensive sealing gas recovery units.

Advantages of oil-lubricated mechanical face seals – maximum leakproofness

As an alternative, oil-lubricated mechanical face seals in ORC-based processes offer a maximum degree of leakproofness. This design option also eliminates the need for a costly and work-intensive sealing gas recovery unit.

But the use of oil-lubricated mechanical seals is not without downsides: Compared to gas, oil is a highly viscous fluid. Used as a sealant medium, it creates a high level of friction between the rings rotating with the turbine shaft and the static rings along the sealing gap. This ultimately leads to increased heat generation at the seal, limiting the maximum rotational speed of a turbine combined with an oil-lubricated face seal. For this reason, a turbine based on such a design may fall short of achieving its maximum efficiency. This method also requires a sealing oil system, which may necessitate degassing of process gas released from the oil. In sum, the initial cost advantage of oil-lubricated seals compared to dry face seals with a sealing oil recovery unit is minimised.

For this reason, neither of the two options is inherently superior to the other. Choosing the right sealing system thereby requires consideration of all project parameters to weigh all the pros and cons of each option.

Power plant for waste heat recovery in Canada

This project leverages waste heat from two gas turbines to generate electricity with a total net output of approx. 2 MW. The turbines are driv-

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Fig. 6: Geothermal power plant in Pamukören, Turkey: epicted in front, the liquid storage tank (white) holding liquid isobutene downstream from the condenser; in the middle, the process-fitted turbine and starting from left, a condenser bay stretching 105 metres in total.
ing pumps in a process for recovering raw oil from oil sands in the Alberta province. The process directs waste heat from the jet blast of the gas turbines towards a heat exchanger, which in turn transfers the heat via a thermal oil cycle to a second heat exchanger. This exchanger serves as the interface to the ORC process. In order to achieve maximum efficiency, the plant was designed as a trans-critical process with R134a as the working fluid, making it one of the first operational processes of its kind.

**Geothermal power plant in Turkey**

One of the world’s largest ORC-based geothermal power plants generates clean power outside the town of Pamukören, Turkey. The plant has been put into operation since October 2013. It consists of two trains, which produce in total more than 40 MW nominal power. The high performance of each train is achieved through a double turbine design, operated in parallel via a gearbox. The plant also features air condensers at 105 x 35 metres in size and heat exchangers covering a total area of 400,000 square metres, adding to the impressive size of the operation.

Currently, an additional geothermal power plant project is being executed in Southern Germany. Construction work has recently begun and the facility will be operational by summer 2014.

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**But when was the last time that air actually impressed you?**
The process air demand of a wastewater treatment plant can be produced with highest possible energy efficiency when it is implemented by various machine types with different ratings.

**Process air production with highest energy efficiency**

- Stephan Brand

In biologically working municipal and industrial wastewater treatment plants the production of oil free process air requires a considerable amount of electrical energy. However, an optimal solution with highest possible energy efficiency can only be achieved when the compressor performances can be adjusted continuously to the alternating consumption due to unsteady waste water quantities and degrees of pollution.
As the consumption not only varies due to the highly fluctuating load in the morning or late at night, but also by additional waste water from industrial plants working during the week and by alternating amount of precipitation. Often seasonal situations need to be considered, e.g. as for holiday areas. Another important influencing factor are high temperature differences e.g. by summer- and winter operation or in regions that are known for extreme amplitudes such as Canada, Russia or others. Only when all criteria are considered for the conception of the process air production, the optimum compressor system will be chosen in the correct configuration. However, the required process air can only be produced with highest-possible energy efficiency when the selected concept has a sufficiently variable performance spectrum and when an optimal selection of basic- and peak load systems will be fully automatically activated demand-related.

In biologically working big sewage plants turbo compressors are often first choice due to their high conveying quantities.

Preconditions for an efficient process air production

An essential base for the optimal operation of a biologically working wastewater treatment plant is the demand-related supply of oxygen in the aeration basins in all load situations in accurately dosed quantity. As for the optimal work of the bacteria neither a too much nor a shortfall of process air is to be avoided. Therefore, for a process air production with highest energy efficiency two preconditions are indispensable:

- The total performance of all installed process air producers must cover the maximum demand of oil-free process air, including a sufficient redundancy service.
- The technology of the installed plants must enable fully-automatically a flexible adjustment of the process air producers to strongly alternating consumption, with minimum maintenance effort and with minimum idle times.

These days, oil-free turbo compressors, positive displacement blowers and rotary lobe compressors are operated in biologically working wastewater treatment plants for the supply of oxygen. Oil-free screw compressors having operated in the meantime or oil-injected plants with subsequent oil-free treatment of the produced process air are these days only operated in exceptional cases. Currently, turbo compressors are mostly used in biologically working big sewage plants as this compressor system distinguishes itself by high conveying quantities, whereas the maximum pressure of 1.0 bar is absolutely sufficient.

However, the technology of the turbo compressors has been improved decisively by the providers since the eighties step-by-step.
Plain- and antifriction bearing, mechanically controlled

The originally used turbo compressors with plain and antifriction bearing type of construction with mechanical control do not correspond anymore to the current state of the art. These turbo machines worked with upstream gearbox and a classic three-phase asynchronous motor with fixed speed. The plants are very big and cause extensive maintenance work by their vast actuating mechanism. In addition, it was only possible by means of filigree technology and to a lesser extent that these systems could be adjusted to fluctuating air consumption by costly mechanical inlet and outlet guide vanes. This system is characterised by very high wear potential.

Air-bearing turbo blowers

Speed-controlled, air-bearing turbo blowers have become broadly established in aeration tanks of biologically working wastewater treatment plants. Thanks to the economical, reliable and low-maintenance operation this new generation replaces more and more the classical roller- and magnetic bearing turbo compressors.

The turbo blowers work with high-speed permanent magnetic motors (PM-motors) and may be adjusted via a frequency converter without additional mechanical adjusting devices infinitely variable between 40% and 100% optimally adjusted to fluctuating process air consumption.

Frequency converter and line choke with RFI-filter are integrated in the units. In these air-cooled PM motors the electromagnetism is used as in usual electric motors, combined with the permanent magnetism of the rotor. Therefore, this rotor does not require any energy for its magnetisation. Only the stator is magnetised electrically. The PM motors distinguish from standard motors by higher efficiency.

Thanks to the turbo impeller directly mounted on the motor shaft, an adjustable, low-maintenance compact unit is the consequence. In case of standstill the shaft is located on a foil strained by springs. Immediately after start-up an air cushion builds up between foil and shaft, however, which is produced by the rotation of the
shaft and not by compressed air. The system works absolutely oil-free. Therefore, in these units the only medium to be compressed is air that is used for the bearing of the shaft and for cooling the system.

A further characteristic feature of these turbo blowers is the impeller made of stainless steel which is corrosion-resistant and robust. Due to its high strength, the walls of the impeller are thinner and, therefore, better aerodynamics and higher efficiency can be achieved as well as the manufactured frequency converter. In case of unforeseen pressure fluctuations an uncontrolled shutdown of the machine to the surge limit can be avoided. This frequency converter is perfectly designed for the safe operation of turbo blowers. Compared to standard converters, this is a big step ahead in terms of operation behaviour and efficiency.

Further developments and their advantages

Speed controlled turbo blowers are available in the following performance ranges:

- Volume flows: 17–220 m³/min (1,000–13,200 m³/h)
- Pressure range: 400–1,000 mbar, higher pressures upon request
- Fields of application: air overpressure production

The new turbo blowers offer the following advantages:

- Further improvement of the energy efficiency by the application of an additional cooling air turbo and an improved cooling air guide within the unit
- Low maintenance and service costs; reliability and durability by absolutely oil-free, contactless air lubricated bearing
- Reduced sound level by innovative acoustic hood and improved sound insulation
- Space-saving installation by immediate side-by-side installation
- High operator convenience, simple installation and commissioning good accessibility to all electronic components by extensible drawer concept, integrated control with touch screen, complete ready-for-connection delivery

In addition, the Turbo does not blow the waste heat into the environment, but provides the

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Speed-controlled, air-bearing turbo blowers have become broadly established in aeration tanks of biologically working wastewater treatment plants.

Compound design concepts for highest possible energy-efficiency

The process air demand of a wastewater treatment plant can be produced with highest possible energy efficiency when it is implemented by various machine types with different ratings, that can be defined as ideal base- and peak load units depending on their constructive features and performance ranges. The physical advantages of a continuous-flow machine – the high efficiency of the design point – can be perfectly combined with the advantages of rotary piston machines – the high controllability and the good efficiency, also in part-load operation. The programme includes the following for the customised process air generation.

- For generation of the base load requirement:
  Adjustable turbo blowers (available volume flows: from 1,000–13,200 m³/h, pressure range from 400–1,000 mbar, control range: 40–100%).

- For generation of peak- or light load requirements:
  • Adjustable positive displacement blower (available volume flows: 100–14,400 m³/h, pressure range from 0–1,000 mbar, control range: 25–100%).
  • Adjustable rotary lobe compressor (available volume flows: 670–5,900 m³/h, pressure range 0–1,500 mbar, control range: 25–100%).

By means of this three-point-programme, the ideal preconditions are established for the implementation of a very energy-efficient process air station. An optimally adapted overall concept, for highest operation safety, reliability and efficiency can be realised.

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The search for the Higgs boson was one of the key scientific projects that were carried out in the Large Hadron Collider (LHC) at CERN. With a circumference of approximately 27 km, the LHC is the largest particle accelerator in the world. Here, particle beams are accelerated to nearly the speed of light and brought to collision. An important factor in the work of the particle accelerator is a powerful and reliable vacuum. The specific requirements relating to the accelerator require customised vacuum technology.
On the trail of the Higgs boson

The European particle physics laboratory, CERN, based in Geneva, Switzerland, is the largest research center for particle physics in the world. Founded in 1954, it houses approximately 2,500 employees and over 10,000 guest scientists from around the world. The main task of CERN is to discover what the universe is made of and how it works. In doing so, the aim is to complete the standard model of elementary particle physics, which describes the basic building blocks of matters and the forces acting between them. This model was missing an important component, which has not yet been experimentally proven: the Higgs boson.

In order to implement its research, CERN operates a number of particle accelerators. The most extraordinary of them is the LHC (Large Hadron Collider), installed in an underground tunnel. Its circumference measures 26.7 km, making it the largest particle accelerator in the world. In the LHC, two opposing particle beams are accelerated to nearly the speed of light and brought to collision at defined locations in large detectors. During this collision process new particles are produced. The records of the detectors provide conclusions about the characteristics of the collided as well as the newly created particles. This way, scientists hoped to be able to prove the Higgs boson. In July 2012, the research groups for the ATLAS and CMS detectors reported that they found the Higgs boson.

This earned Peter Higgs of Britain and François Englert of Belgium the 2013 Nobel Prize in Physics. As early as in the 1960s, the two scientists predicted the existence of this particle in their theories and thus contributed significantly to our understanding of particle physics.

To meet the high demands of a particle accelerator, special vacuum solutions for vacuum generation, vacuum measurement and vacuum analysis had to be developed and implemented.

The importance of vacuum

An important factor for the operation of a particle accelerator is a reliable, powerful vacuum system. However, an extraordinary machine such as the LHC also has very specific requirements for the installed vacuum technology. The smallest errors could put the entire accelerator out of service for several hours. Therefore, the entire vacuum system must be extremely reliable. In addition, all equipment used within the accelerator must be able to withstand radiation levels of up to 1,000 Gy/a.

Equipment leaving the accelerator’s radiation area for reasons such as maintenance must undergo very complex measurements. For this reason, it is extremely important that the equipment can be maintained on-site. In order to meet these especially stringent requirements, special vacuum solutions for vacuum generation, measurement and vacuum analysis were developed and implemented in coordination with CERN.

Fig. 1: The Large Hadron Collider at CERN: In a 26.7 km long underground ring tunnel (marked by the yellow line) protons or lead nuclei are accelerated to nearly the speed of light in opposite directions and brought to collision.
Vacuum generation

The LHC differentiates between two vacuum systems: the beam vacuum and the insulation vacuum.

Turbopumps are used for both applications. These were modified to fulfill the special requirements of the LHC. In order to be able to operate the turbopumps in the radioactive radiation, no electronic components can be used in the pumps. For this purpose, a sensor-free drive concept was developed which makes it possible to completely separate the mechanical part of the pump and the electronics from each other. Using this concept, the electronics can be located up to 1,000 m away from the turbopump and localised in a shielded area.

Beam vacuum

In order to prevent the fast particles from colliding with gas molecules on their paths through the accelerator, the beam lines must be under an ultra-high vacuum of $10^{-11}$ hPa. This so-called beam vacuum is created in a multi-stage pumping process.

First, the beam lines are pre-evacuated to $10^{-8}$ hPa using turbopumps. The advantage of these pumps is that they have a very large compression ratio for light gases. This is especially important as hydrogen, the lightest gas in the atmosphere, determines the ultimate pressure in the ultra-high vacuum domain. After the pre-evacuation, a NEG (Non-Evaporable Getter) coating developed by CERN is thermally activated inside the beam lines. This coating acts as an additional absorption vacuum pump for gas. It absorbs the remaining gas molecules, creating the necessary ultimate pressure of $10^{-11}$ hPa.

Insulation vacuum

Extremely powerful superconducting magnets, cooled down with liquid helium to 1.9 K (approx. –271 °C), ensure that the particles in the LHC are kept in their orbit. To maintain the low temperature of the magnets, a good thermal insulation of the entire cooling system is essential. For this purpose, an insulation vacuum, similar to a thermos flask, is created around the magnets.
which reduces the heat input into the cryogenic system to a minimum. The insulation vacuum must be permanently maintained at < 10^{-6} hPa. As superfluous helium always leaks into the insulation vacuum due to unavoidable leaks in the cooling system, turbopumps are permanently in use in order to maintain the insulation vacuum. Due to its high pumping capacity and the large compression ratio for light gases, the turbopumps are particularly suitable for pumping down helium.

**Helium leak detection**

For the ultra-high vacuum pressures required for the LHC, it is important that the components used for the accelerator have extremely low leakage rates. Therefore, before installing the components, an extensive leak test is essential. For the leak tests, CERN uses helium leak detectors. Using these, even the smallest leakages of 10^{-13} Pa m^{3}/s can be detected reliably.

**Vacuum measurement**

The generated vacuum is measured with specially developed measuring devices. The devices used are modified Pirani and cold-cathode vacuum gauges. They permanently monitor the pressure in the accelerator and ensure that, in the case of an increase in pressure, appropriate action can be taken. As the vacuum gauges are also exposed to high radioactive radiation, they are constructed as passive sensors without integrated electronics. All electronics are housed in a radiation-safe area and are connected to the passive sensors via long cables. The required cables were evaluated in close collaboration with CERN. This allows the cold cathode vacuum gauges to measure pressures up to 10^{-11} hPa. A special ignition process offers the advantage of enabling the cold cathode vacuum gauges to be turned on easily even at very low pressures. As the lifetime of an accelerator is approximately 30 to 40 years, only electronic components that will be available for a long time were selected.

**Vacuum analysis**

Not only the pressure but also the composition of the residual gas is an important factor for the proper operation of the accelerator. Using a residual gas spectrum, conclusions can be drawn about the outgassing of the materials used in the accelerator. To record residual gas spectra, CERN uses mass spectrometers. For this residual gas measurement in ultra-high vacuum, it is especially important that the analyzers of the mass spectrometers themselves demonstrate a low outgassing rate. In addition to a vacuum-annealed ion source, the analyzers used at CERN also have a vacuum-annealed rod system. Therefore, these analyzers produce an extremely low underground signal and are thus particularly well-placed in order to record the actual residual gas ratios in the accelerator.
Interview at CERN
A conversation with Dr. José Miguel Jimenez,
Head of CERN’s Vacuum, Surfaces & Coatings (TE/VSC) Group

Dr. Jimenez, how do you feel working at one of the world’s largest and most respected centers for scientific research?

I am very proud and happy to work with CERN. Looking at it from the outside, many people only see the work of basic physics research. Technologically demanding developments are necessary in order for CERN to conduct the research, and all this is done in international cooperation.

As an engineer, I am excited to see the different technologies that are used for the accelerators.

Which role does the vacuum technology play in CERN’s research work?

Regarding the role of vacuum technology in our research work, without a very good ultra-high vacuum, the accelerator and the detectors would not be able to operate.

What is the purpose of vacuum technology in the LHC accelerator ring?

Vacuum technology is used to generate beam and insulation vacuum in the accelerator. Beam vacuum is particularly important for our high-energy accelerators. For this purpose, pressures of $10^{-10}$ hPa are required in beam operation and $10^{-12}$ hPa in standby mode. Beam vacuum is particularly important in the area before and after the experiments.
There, the collisions between beam particles and the remaining gas molecules in the accelerator must be reduced to a minimum. The higher the vacuum pressure, the more of these collisions will occur. Radiation is generated with each collision, this affects the background of the detectors, resulting in damage to the detectors. In order to maintain the insulation vacuum, we use turbopumps. Those are used to pump the helium exiting from the cooling system out of the cryostat.

Even though the deflecting magnets are operated at 1.9 K (approximately −271 °C), the amount of helium that we can condense on the cold surfaces is very low. This is because helium has a very low condensation temperature. With an extremely long and complex liquid helium circulation, very small helium leaks can occur. Therefore, we must maintain a pumping capacity to be able to continue the insulation vacuum and so also maintain the operation of the accelerator.

Most of the vacuum technology we need at CERN is available on the market. The problem is the integration of this technology into the very specific environment of the accelerator. These requirements make it necessary to develop customised vacuum technologies for the LHC and for all other CERN accelerators.

Which special requirements must be fulfilled by the pumping system?

A powerful vacuum system is important for the successful operation of a particle accelerator. It must have high reliability, withstand electromagnetic fields and radiation and must ensure easy maintenance.

Which specific advantages of the turbopumps are required in this application?

In the LHC, the turbopumps have to provide a huge compression rate for helium and hydrogen, in order to allow very low final vacuum. The pumps must be resistant to electromagnetic fields and radiation. Their reliability must be very high to reduce LHC down-time. Some of them require being able to withstand long bake-out cycles of more than 24 hours at 250 °C, to reduce the final vacuum even further.

Please describe briefly the specificity of the environmental conditions in the accelerator ring. How did the turbopumps have to be modified?

Take, for example, the pumps for the insulation vacuum that are permanently installed on the cryostat. At 1.9 K (about −271 °C), only a small fraction of the helium gas can be condensed. If a small leak occurs in these complex cryogenic circuits, the installed turbopumps will ensure that the LHC continues to operate. These pumps must be resistant to electromagnetic interference resulting from the magnets.

Above all, they must be resistant to radiation that occurs during the operation of the LHC. To be suitable for the operation on the LHC, the turbopumps have to withstand a radiation dose of up to 1,000 Gy/a. This level of radiation prevents the use of semiconductor components in the interior of the pump. To overcome this problem, we are using a new sensor-free drive concept. This concept allows the complete removal of all electronic components from the pump body to a shielded area outside the tunnel. Although the electronics are positioned far away from the pump, they can still notify the users of all the important status parameters of the turbopump.

How important for you is the technical support in terms of the vacuum components?

All objects leaving the controlled area at CERN must undergo very complex release controls. Despite the fact that it is very unlikely that the components of the vacuum system might get activated in terms of radiation and contaminated, even for service reasons a complex procedure has to be undertaken to declassify the products to be able ship them outside the controlled area.

Therefore, it is very important to us that the installed equipment can be serviced by service technicians on site.

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Reducing carbon footprint with the right vacuum system

Josef Karbassi

The consumption of fossil fuels is one of the main causes for the increase of CO₂ in the atmosphere. Today, electricity is still primarily generated by power stations fired by gas, oil or coal. Reducing electricity consumption in industrial systems can therefore make a great contribution to improving the carbon footprint. One approach is to review the use of vacuum systems for material handling procedures. Here ultra-modern technology can clearly reduce energy consumption and improve the carbon footprint.
Calculating vacuum system energy consumption and CO₂ emissions

The most common vacuum technology for handling sealed materials today like sheet metal, plastic and glass utilises air-driven vacuum ejectors. The handling system is quite often based on a robot equipped with vacuum lifting devices and suction cups. There are also many manual vacuum handling devices designed for sealed objects, as well as dedicated machinery with integrated vacuum handling systems. Examples include sheet-metal presses, water and laser cutters, and glass and woodworking machines. The energy consumed by these types of vacuum handling systems is defined by how much compressed air the ejector consumes to create vacuum, and often takes into account how much compressed air is needed in the blow function to release the part quickly enough.

The amount of compressed air consumed in an ejector when vacuum is created depends on the number of nozzle rows, the size of the smallest diameter in the first ejector nozzle, and the compressed air feed pressure. The complete formula to theoretically calculate the air consumption for an ejector nozzle is seen in Fig. 1.

It is quite common that the specified air consumption for ejectors will differ from the theoretical value. The actual air consumption should be very close to the theoretic value (the difference of a few percentages is reasonable). Fig. 2 demonstrates the theoretic value for some common nozzle diameters at varying feed pressures. Calculations are made at a temperature of 10 degrees Celsius (283.16 degrees Kelvin).

The other, and quite often forgotten, energy thief in a vacuum handling system designed for sealed materials is the blow-off function, which is used for quick release of the object. The air consumed during blow-off is determined by the flow capacity of the valve that controls the function and pressure being used. When utilising a large centrally placed ejector (i.e. many cups connected to the same source), very high levels of flow are required in order to quickly break the seal on remotely placed suction cups. In this case, flow levels in the range of 200–500 Nl/min at 4–6 bars are standard.

In a decentralised system using one small ejector at each point-of-suction, the release function is in many cases the result of blocking the exhaust. The air travelling through the ejector will be forced into the cup so the air consumption will be equal to, or slightly higher than, the
Air consumption for producing vacuum. An alternative solution is a small blow-off check valve on a decentralised unit, which typically allows 100–200 Nl/min to pass through at 4-6 bars.

In order to calculate the energy consumed, it is required that the compressor efficiency is known. A normal sized compressor, able to create 7–10 bars of pressure, consumes 6–10 kW per produced cubic meter of air depending on size and efficiency. The total air consumption for an ejector system per year can easily be calculated by adding the air consumed by vacuum production and the air consumed by blow-off function in each cycle, and then multiplying by the number of cycles per year. Even better is to measure the consumption with a flow meter over the course of a number of cycles.

The CO₂ emissions per produced kWh of electric power will be as follows, depending on the type of production:

- Gas: 0.2 kg CO₂/kWh
- Oil: 0.27 kg CO₂/kWh
- Coal: 0.33 kg CO₂/kWh
- Nuclear, wind, water: 0.0007 kg CO₂/kWh

Re-calculated for compressed air production, the result is 0.02–0.033 kg CO₂/m³ if only considering the “dirty” production methods and basing the compressor efficiency on 10 kW per produced cubic metre of air.

How to reduce vacuum system carbon footprint to a minimum

The ejector’s efficiency is obviously an important parameter to focus on when attempting to minimise energy/air consumption. Ejector efficiency is determined by the vacuum performance (flow and speed of evacuation) in relation to air consumption. Basically, there are two main types of ejectors used in sealed vacuum handling systems today – single-stage ejectors and multistage ejectors.
The multistage design is more complex and requires more space, but it will always be 15–50 percent more efficient (same speed/response time with less energy consumption). Therefore, it is important to use a multistage ejector whenever possible.

When ejector technology entered the market for vacuum material handling of sealed parts and started to replace electrical driven vacuum pumps, the main reasons were the reliability of the products, as well as the ability to easily control the ejectors’ power during operation.

The ejector’s efficiency is obviously an important parameter to focus on when attempting to minimise energy/air consumption.

At that time, small ejectors were placed on each suction cup, forming a decentralised system. In many cases, a decentralised system such as this is the most efficient system, as it places suction exactly where it is needed. There is no need for over-dimensioned ejectors to compensate for losses and extra volume. There is also a reduced risk of leakage from fittings and couplings.

However, when “air-saving technology” became available for ejectors, a new trend began: So called “compact ejectors” (or “smart ejectors”) with integrated control functions such as valves, vacuum switches and air-saving functions flooded the market. These compact ejectors are centrally placed and serve several suction cups. They are usually located a few meters away from the points-of-suction. The air-saving function turns the ejector off when enough vacuum pressure is created, and turns it back on to compensate for any leakage occurring in the system. One major advantage of this system is that the centralised ejector with air-saving function only works for a short period of time during the vacuum duty cycle, and energy will be saved when compared to the previous decentralised concept.

With the centralised compact ejectors, factors like operational reliability and safety (one ejector per cup), and speed of vacuum generation and object release must be sacrificed to a certain degree. Speed can be compensated for with a very large centralised ejector, but this means much greater energy consumption. Another issue in utilising centralised compact ejectors is that the blow-off function has to be very powerful in order to release parts quickly enough. This is because pipes are long and often restricted, leading to large amounts of air consumption during the time needed for blowoff.

Fig. 3 below shows a typical work cycle in a sealed vacuum handling application utilising a compact ejector with air-saving function.

- Dark blue: vacuum is started in the system before the actual pick to increase pick-up speed.
- Grey: pump is working in duty cycle, compensating for leakage.
- Blue: vacuum is started in the system before the actual pick to increase pick-up speed.
- Green: return to start position.
- Orange: vacuum pump “on” before pick up / actual pick.
- Red: actual release.
- Cyan: pump working in duty cycle, compensating for leakage.
- Yellow: total compressed air supply per cycle for blow-off function.

Source: Piab
Can air consumption and carbon footprint be substantially reduced?

A new, compact, decentralised ejector unit with two unique features is the answer to the question of whether air consumption and carbon footprint can be substantially reduced with a vacuum system: a fully pneumatic and internal air-saving device and a new release valve, which uses the ambient atmosphere to quickly release a handled part.

The volume of a single suction cup is so low that atmospheric air is all that is needed. In other words, no compressed air is needed for release, and an automatic air-saving device is in place. This concept offers all the benefits of a decentralised ejector system in terms of reliability, safety and speed (response and release). The air and energy consumed is virtually nonexistent. There is no compressed air consumption during the release of objects, and the air-saving function does not have to compensate for leakage from multiple fittings and couplings. The volume is so low that the air-saving function will start almost instantly. Time that the ejector must be on before pick-up is also reduced to almost nothing, and there is no need to create a pre-vacuum in the system. It will be fast regardless. As Fig. 5 highlights, the pump is only working for an extremely short period of time. Now we will look at a typical sealed vacuum handling application:

- Previous developed decentralised solutions use approximately 25,000–40,000 m³ of air per year.*
- A compact ejector with air-saving function will reduce air consumption to approximately 15,000–20,000 m³ of air per year.*
- The new solution will use about 1,000 m³ of air per year.

*Range varies greatly as it depends on whether single or multistage ejector technology is used.

It is obvious that even with an air-saving function in place, there will be a great deal of compressed air consumed during each cycle.
It is possible to reduce energy consumption by 90–99 percent by simply using the latest vacuum handling technology.

Returning to our previous equation, we can calculate that 15,000–40,000 m³ of air corresponds to approximately 450–1,200 kg of carbon dioxide emissions if the electrical power is supplied by a coal, oil or gas plant. This is based only on a single application/station. A typical automotive plant can have up to 400 of these applications in operation. The carbon footprint of vacuum handling in these plants can be between 180,000 and 480,000 kg when utilising traditional vacuum technology (based on conditions above). When utilising the new technology, the carbon footprint can be reduced to only 12,000 kg. In comparison, the average amount of CO₂ emitted from one car is 180 g/km. The reduced carbon footprint an automotive plant can achieve per year by using the latest vacuum handling technology corresponds to 933,333–2,600,000 km of driving.

### Reduced cost of energy as a bonus

Today, the CO₂ tax for European industries is between 0.015 – 0.03 € per kg. An automotive plants could save more than 15,000 € in taxes alone when switching to the latest technology for vacuum handling. This is a major benefit, as higher future taxes seem unavoidable. Ultimately though, the biggest cost savings will come from saved electricity. The typical cost for producing compressed air in a plant with a normal sized compressor (if considering price per kWh, life cycle, interest rate, purchase price, service cost, working hours per year, etc.) is usually be in the range of 1–1.2 euro-cents per cubic meter of air.

An automotive plant with 400 vacuum handling applications could easily save 67,000–187,000 € per year in energy costs along if the latest technology is installed.

**Author:**
Josef Karbassi  
PIAB Business Unit Manager, Automotive  
Piab Vakuum GmbH, Butzbach

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**Cycle analysis of a centralised compact ejector, new solution**

<table>
<thead>
<tr>
<th>Vacum pump “on” before pick up / actual pick</th>
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<tr>
<td>Vacuum duty cycle</td>
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<tr>
<td>Pump working in vacuum duty cycle</td>
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<tr>
<td>Release by Atmospheric Quick Release Valve</td>
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<td>– no air consumption</td>
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<td>Return to start position</td>
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*Source: Piab*
Oerlikon Leybold Vacuum:
TURBOVAC i – the new dimension in turbomolecular pump engineering

The innovative turbomolecular pumps of the TURBOVAC i product line always deliver their maximum performance even under widely differing requirements. TURBOVAC (T)350 i, (T)450i and 350/450 i Multi-Inlet – the performance leap for your vacuum!

www.oerlikon.com/leyboldvacuum

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Pfeiffer Vacuum:
Helium recovery units – the perfect technology for reducing helium costs

Pfeiffer Vacuum develops and manufactures leak detection systems for any facility requiring high throughput production when a tightness criteria of parts needs to be guaranteed. The company also provides a wide range of leak detectors using helium or hydrogen as tracer gas for a wide variety of applications.

www.pfeiffer-vacuum.de

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Data logger METPOINT® BDL made by BEKO TECHNOLOGIES

METPOINT® BDL is the name of the first data logger that specifically focuses on the employment in compressed-air plants. The device which has been developed by the compressed-air system specialist BEKO TECHNOLOGIES GMBH optionally allows for the connection of up to 12 sensors, depending on the model. 32 limit values on the whole can be freely defined and assigned to different alarm relays.

www.beko-technologies.com

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Read more in our online magazine under www.vdmashop.de/puco
KAESER KOMPRESSOREN: Efficient compressed air production with full-flow regeneration
i.HOC is the new integrated attachment rotation dryer for dry-running rotary screw compressors from Kaeser Kompressoren. It provides a reliable and stable supply of compressed air with pressure dew points to minus 40 degrees Celsius, even in challenging environmental conditions – and also saves energy.
www.kaeser.com

NEA reciprocating compressor increases oil and gas yield
Enhanced Oil Recovery (EOR) methods significantly increase oil and gas extraction yields. In this context, NEUMAN & ESSER (NEA) developed a concept saving the operator time and money. The NEA compressor solution for gas injection of carbon dioxide (CO₂) has already proven to be successful in practice as an example in the USA has demonstrated.
www.neuman-esser.com

The Cozzani system for energy saving on reciprocating compressors
Ongoing positive experience of the stepless capacity control system FluxtoFlow™. Designed and developed by Dott. Ing. Mario Cozzani srl, is the first in the world completely electronic stepless capacity control system and successfully present in the market.
www.cozzani.com

ALmiG: Maximum operating convenience with the new AIR CONTROL family
The compressor controls of the AIR CONTROL range have a long track record and have set a high standard on the market in terms of reliability and operating convenience. The new generation incorporates a wealth of innovative ideas and technologies with the aim of achieving maximum user-friendliness. Simplicity of operation is very important.
www.almig.de

Read more in our online magazine under www.vdmashop.de/puco
BORSIG ZM Compression GmbH: 
Process control, safety and monitoring in one system for your compressor unit
BORSIG ZM Compression GmbH offers the highly available BORSIG BlueLine automation system with scalable redundancy and up to Sil3 (safety integrity level) for industrial use. The system combines control system, functional safety and machine monitoring for reciprocating and centrifugal compressors by BORSIG as well by other manufacturers.

www.borsig.de/zm

Schneider airsystems: 
Modular screw compressors
Schneider airsystems provides a range of 100 different compressor types in 12 categories of performance from 2.2 kW to 45 kW and three pressure ratings (8 bar, 10 bar and 13 bar). An innovative modular system is being offered in the compressor category 4 kW to 22 kW.

www.schneider-airsystems.com
## Applications
### Process & Compressed Air Technology

<table>
<thead>
<tr>
<th>Technology</th>
<th>Food + Agriculture</th>
<th>Medical Technology</th>
<th>Packaging (Excl. Food)</th>
<th>Laboratory</th>
<th>Oil/Gas</th>
<th>Natural Gas Industry</th>
<th>Oilfields</th>
<th>Petrochemical Industry</th>
<th>Refineries</th>
<th>Biogas</th>
<th>Gas Stations (Natural Gas, LPG)</th>
<th>Hardener/Workshops</th>
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### Companies

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<td>ALMiG Kompressoren GmbH</td>
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## Applications

### Process & Compressed Air Technology

- 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

- Garages
- Workshops

### Pneumatic

- Mechanical engineering

### Switchgear

- 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
- Oilfield 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
## Applications

### Process & Compressed Air Technology

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*Körting Hannover AG: www.koerting.de*

*MAN Diesel & Turbo SE: www.mandieselturbo.com*

*METAPIPE GmbH: www.metapipe.de*

*MTA Deutschland GmbH: www.mta.de*

*Nash – Zweigniederlassung der Gardner Denver Deutschland GmbH / www.CDNash.com*

*Neuenhauser Kompressorenbau GmbH: www.nk-air.com*

*NEUMAN & ESSER GROUP: www.neuman-esser.com*

*Parker Hannifin GmbH, Hiross Zander Division: www.parker.com/hzd*

*Piab Vakuum GmbH: www.piab.com*

*Sera ComPress GmbH: www.sera-web.com*

*Ultrafilter GmbH: www.ultraair.de / www.ultra-filter.de*

*WIKA Alexander Wiegand SE & Co. KG: www.wika.de*
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<th>Applications</th>
<th>Technology</th>
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<td>Process &amp; Compressed Air Technology</td>
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<td>Other fields of applications</td>
<td>Drying</td>
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<td>Drives</td>
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<td>Heat recovery</td>
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</tbody>
</table>
# Applications

## Vacuum Technology


1. (Metal Degassing, Melting, Re-melting, e-beam welding, casting, ...)
2. (Brazing, Carburising, Nitriding, Quenching, ...)
3. (c-Si, Thin film deposition, Laminating, ...)
4. for Semiconductor including focused ion beam systems and electron beam systems
5. (Driers, Centrifuges, Concentrators, ...)

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**Pumps and Compressors for the World Market with Compressed Air and Vacuum Technology 2014**
<table>
<thead>
<tr>
<th>Applications</th>
<th>Vacuum Technology</th>
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# Applications

## Vacuum Technology

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<td>VACOM Vakuum Komponenten &amp; Messtechnik GmbH</td>
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1. (Metal Degassing, Melting, Re-melting, e-beam welding, casting, …)
2. (Brazing, Carburising, Nitriding, Quenching, …)
3. (c-Si, Thin film deposition, Laminating, …)
4. for Semiconductor including focused ion beam systems and electron beam systems
5. (Driers, Centrifuges, Concentrators, …)
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<td>Thin-Film Deposition (non-Semiconductor)</td>
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<td>Data storage (CD, DVD, Hi Def. Disc, ...)</td>
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<td>Surface Coating (wear protection, decorative, ...)</td>
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</table>
Brand name & trade fair register

Alltech Dosieranlagen GmbH
Rudolf-Diesel-Str. 2
76356 Weingarten
Phone +49 7244 7026-0
Fax +49 7244 7026-50
info@alltech-dosieranlagen.de
www.alltech-dosieranlagen.de

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IFAT, München, 5–9/5 2014, Hall A2, Stand 5B4

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www.becker-international.com

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• Screw compressors and vacuum pumps
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FAT, München, 5–9/5 2014
Interpack, Düsseldorf, 8–14/5 2014

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Fax +49 3764 5390-5092
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NEFTEGAZ, Moscow, Russia, 26–29/5 2014
9th EFRC Conference, Vienna, Austria, 11–12/9 2014
18th Workshop Kolbenverdichter, Rheine, 22–23/10 2014
ADIPEC, Abu Dhabi, UAE, 10–13/11 2014
OSMA, Singapore, 2–5/2 2014
For further information, please refer to www.borsig.de/zm

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Maschinenfabrik & Co. KG
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Fax +49 2302 690-443
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EDS Conference, Cyprus, 12–14/5 2014
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Electra Mining, Johannesburg, South Africa, 25–19/9 2014
Mining Turkey, Istanbul, 27–30/11 2014
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Hannover Messe, Hannover, Pumpe DE Pumpenplatz, 7–11/4 2014
IFAT München, 5–9/5 2014
partizilean, Stuttgart, 24–26/6 2014
Fakuma, Friedrichshafen, 14–18/10 2014

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www.homa-pumpen.de

KLAUS UNION GmbH & Co. KG
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DIN EN- and API-685 series and pumps beyond standard.

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15–18/9 2014
Expoquimia 2014, Barcelona, Spain,
29/9–3/10 2014
Adipec, Abu Dhabi, UAE,
10–13/11 2014
Valve World Expo, Düsseldorf,
2–4/12 2014
More exhibitions in 2014 please visit:
www.klaus-union.com

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Fax +49 2392 935-209
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www.kracht.eu

We at KRACHT, a medium-sized, family-run business, are a globally active company with 290 employees
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Automotive Testing Expo 2014,
Stuttgart, 24–26/6 2014
UTECH ASIA 2014, Shanghai, China,
3–5/9 2014
SMi 2014, Hamburg,
9–12/9 2014
bauma China 2014, Shanghai, China,
25–28/11 2014

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www.ktr.com

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high-power brake systems we are the right partner
for all those who want to set things in motion.

Hannover Messe, Hannover,
7–12/4 2014
IFAT ENTSORGA, Munich,
5–9/5 2014
Pump Summit, Düsseldorf,
2–3/12 2014
Further exhibition dates see
www.ktr.com

LEISTRITZ PUMPEN GMBH
Marlkraftstr. 29–39
90459 Nürnberg
Phone +49 911 4306-0
Fax +49 911 4306-490
pumpen@leistritz.com
www.leistritz.com

Leistritz Pumpen GmbH has been producing and
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have internal or external bearings with single- or
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the Type Series L2, L3, L4, L5 with 2 to 5 spindles
and offers solutions for a wide range of applications, for
example the oil or gas as well as chemical industry.

Arab Oil Dubai, UAE,
17–19/3 2014
CPPE 2014, Beijing, China,
18–21/3 2014
Neftegaz Moscow, Russia,
26–29/5 2014
SMi Hamburg, 9–12/9 2014
KOGE Almaty, Kazakhstan,
30/9–3/10 2014
ATCE Amsterdam, Netherlands,
27–29/10 2014
Adipec Abu Dhabi, UAE,
10–13/11 2014
Josef Mehrer GmbH & Co. KG
Rosenfelder Str. 35
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NETZSCHE GAZ, Moscow, Russia, 26-29/5/2014
ERCF, Vienna, Austria, 10-12/9/2014
gast / wat, Karlsruhe, 30/9-10/10/2014
TURKISHMEN, Istanbul, Turkey, 16-18/10/2014
Brau Beviale, Nürnberg, 11-13/11/2014
Blogs Jahres tagung & Fachmesse, Bremen, 27-29/11/2015

Brand name & Trade fair registration

NETZSCHE Pumpen & Systeme GmbH
Gerefsrieder Str. 1
84478 Waldkraiburg
Phone +49 8638 63-0
Fax +49 8638 67981
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IFAT, Munich, 5-9/5/2014, Hall A6, Stand 139/240
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HET Instruments, Amsterdam, Netherlands, 30/9-3/10/2014
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Brand name & Trade fair register 117
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<thead>
<tr>
<th>Company</th>
<th>Internet address</th>
<th>Placement</th>
</tr>
</thead>
<tbody>
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<td>ALMiG Kompressoren GmbH</td>
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<td>Page 21</td>
</tr>
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<td>Page 17</td>
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<td>Page 98</td>
</tr>
<tr>
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<td>Page 57</td>
</tr>
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</tr>
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<td>Page 15</td>
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<td>Page 99</td>
</tr>
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<td>Page 63</td>
</tr>
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<td>Page 95</td>
</tr>
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<td>Page 23</td>
</tr>
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<td>Page 33</td>
</tr>
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<td>Page 47</td>
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<td>Page 13</td>
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<td>Page 55</td>
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<td>Page 79</td>
</tr>
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<td>Page 19</td>
</tr>
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<td>Page 93</td>
</tr>
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<td>Page 51</td>
</tr>
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<td>Page 3</td>
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<td>Page 7</td>
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<td>Page 49</td>
</tr>
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<td>Page 27</td>
</tr>
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<td>Page 90</td>
</tr>
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<td>Page 11</td>
</tr>
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<td><a href="http://www.oerlikon.com/leyboldvacuum">www.oerlikon.com/leyboldvacuum</a></td>
<td>Page 83</td>
</tr>
<tr>
<td>Pfeiffer Vacuum GmbH</td>
<td><a href="http://www.pfeiffer-vacuum.de">www.pfeiffer-vacuum.de</a></td>
<td>Inside cover page</td>
</tr>
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<td>Page 31</td>
</tr>
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<td>Page 39</td>
</tr>
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<td>Page 35</td>
</tr>
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</tr>
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<td>Page 101</td>
</tr>
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<td>Page 43</td>
</tr>
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<td>Page 53</td>
</tr>
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<td>Page 9</td>
</tr>
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<td>Page 61</td>
</tr>
</tbody>
</table>
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