ESSENTIAL

FREUDENBERG SEALING TECHNOLOGIES

THE MAGAZINE – ISSUE #1 2017

DYNAMICS

Force, movement, change –
whatever gets things moving and drives developments.

NEWS FROM HYDRAULICS

Key technology:
The modern side of “Fluid Power” in Las Vegas.

HOW DOES INNOVATION SUCCEED?

Double interview: What strength of leadership and radicalism has to do with far-sighted future planning.

ENERGY WITH BATTERIES

Why the auto industry is betting on electric mobility –
and the role that seals can play in it.

DYNAMICS – WHAT IS IT ACTUALLY?

Depending on the context of its use, the term is actually quite multilayered. Movement, force, change – all these themes can be described as “dynamic.” This is exactly what the following pages are designed to address.

We first emphasize new developments and changes in the hydraulic area, a key technology that can produce a great deal of force and movement.

In the truest sense of the phrase, the term also deals with dynamic developments: How do people succeed at innovation? Where is robotics headed? What is going on with Industry 4.0 as an issue for the future? In many of these cases, we are able to offer our very own examples from the universe of Freudenberg Sealing Technologies.

Electric mobility combines motion, innovation and dynamics: Here we take a look at the latest trends and delve deeply into the future of the lithium ion battery.

Join us on a trip through a world that is dynamic in a great many respects.

THE MAGAZINE online:
http://essential.fst.com

CONTENTS

PAGE 10–17

THE FORCE OF THE WORLD

Dynamics gets things going. But what exactly is behind this phrase? On a trail that forces us to take different perspectives.

PAGE 18–19

LIFE-EXTENSION MEASURES

At Freudenberg Sealing Technologies, Joel Johnson is responsible for the mobile equipment business. In an interview, he talks about the advantages of modern seals for construction and agricultural machinery.

PAGE 20–25

PLAY IT AGAIN

This year’s International Fluid Power Exposition (IFPE) in Las Vegas offered an interesting view of the latest developments in hydraulic drive technology.

PAGE 34–39

“IF YOU ARE AFRAID TO FAIL, YOU WON’T BE INNOVATIVE”

Stanford Professor Charles O’Reilly and FST innovation expert Dr. Jan Kuiken discuss innovation as the driving force of successful companies.

PAGE 40–43

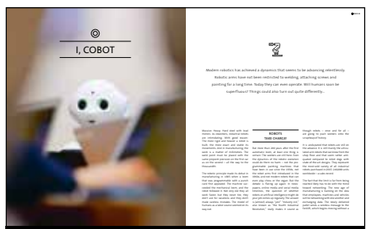
LONGER LIFE

A specialist in mining technology, Atlas Copco produces rock boring drills that are considered to be especially robust and durable. One crucial guarantee of success: efficient seals.

PAGE 44–47

FRICTION-FREE LAUNCH

The new Levitex mechanical face seal from Freudenberg Sealing Technologies is about to be manufactured in short production runs in the north Italian city of Pinerolo.



PAGE 48–51

I, COBOT

Industrial robots still have the reputation of being job destroyers. With the new generation of collaborating robots, things could turn out differently.

PAGE 60–63

IN THE FLOW OF FORCES

Our experts are in demand whenever the job is to develop the right material for a new seal.

PAGE 64–67

DILIGENT WORK FOR THE REVOLUTION

What technologies do vehicles need to run autonomously, emission-free and networked in the future? The specialists at IAV, an engineering firm devoted to the automobile and transportation, are looking into these issues.

QUIET AS A WHISPER

Shimmering asphalt, revving engines, spinning tires – hundreds of horsepower are already propelling the car toward the first curve with a deafening roar. Pure power and dynamic energy. That is the Formula 1 experience. These aerodynamic, high-tech projectiles barely need 1.7 seconds to accelerate to 100 km/h (62 mph). But the “grimsel,” a race car from ETH Zürich University and Lucerne University of Applied Sciences and Arts (both Switzerland), even undercuts this paltry figure. It requires a mere 1.513 seconds and less than 30 meters to reach 100 km/h – without a howling engine. The “grimsel,” an electric race car, demonstrates that electric mobility can certainly be dynamic.

THERE'S SOMETHING IN THE AIR

Paris tourists are familiar with them: cans filled with Paris air. A veritable flash-in-the pan, which says more about the business sense of their distributor than their invisible contents. How so? There is actually more to air than meets the eye. Researchers are now working on producing polymers from the air. Theoretically, it's possible to even create complete seals from this resource. Is this all just bluster? Not at all. Air consists of oxygen, nitrogen, hydrogen and carbon atoms – just like a polyurethane seal. A space of 27 cubic meters contains the molecules needed for a seal. Now the atoms just have to be rearranged to make air a big seller again.

FROM RAILS TO TUBES

As the steam locomotive began its triumphal expansion in the 19th century, people began to perceive space and time entirely differently. Relatively long distances could suddenly be covered quickly. How quickly? Locomotives could travel 30 kilometers per hour (18 mph). Critics thought that was much too fast. The medical faculty in Erlangen (Germany) expressed the view that passengers would suffer brain ailments. But in the future, people are even expected to travel at supersonic speeds on land. The Hyperloop is designed to use the power of a partial vacuum to convey passengers in transportation capsules through tubes at 1,200 km/h (750 mph). Engineers are now delving into the feasibility of the idea. What would the Erlangen doctors say about that?

THE FORCE OF THE WORLD

Dynamics is a term used in very different ways. But this much is clear:
It is regarded positively, and it combines force, movement, power and energy.
What does dynamic mean today? Who puts all the forces around us in motion?
How does it involve us? We track the concept down.

Click. A small ball is launched onto a track. It rolls down an incline and around a curve. It picks up speed. The start of a journey.

Until a short while ago, “young and dynamic” was a common cliché when someone wanted to describe his company, team or himself as positively as possible. Young and dynamic. It sounds like energy, certainly forward-looking. If someone is still young and dynamic, nothing throws him off course. He has everything ahead of him. He can go to work and start things rolling.

No question: Being dynamic – that’s good. Or is it?

#1
DYNAMICS. WHAT DOES IT ACTUALLY MEAN?

The ball races beneath a paddlewheel and spurs it, along a small bell, which begins to ring vigorously and collides with its full force against a closing mechanism, which disengages and sets a small hammer in motion.

Dynamics is a multilayered word. This begins deep in the roots of the word’s meaning. The Greek word **δυναμική** (dynamiké) means powerful, and the substantive **δύναμις** (dýnamis) roughly means “force.” Newly coined words emerged from the two roots. In physics, dynamics is the science of the effect of forces. Anyone using the term in the presence of a professional musician or composer is understood entirely differently – the term is a specification of loudness. In everyday speech, people often mean particularly energy-charged (“dynamic movement”) or quite generally the development (“dynamic”) of things. Dynamics is élan, enthusiasm, liveliness. If someone is dynamic, he is considered diligent and zealous, and certainly nimble and flexible.

This idea also emerges from its opposite: Standstill is ultimately a synonym for death. Life in our world as we know it, our climate and gravity, is only possible because the earth rotates. People are only alive because their heart keeps the blood-stream moving without interruption. We are all constantly in motion and release forces that trigger other things. Even someone sitting at a desk or standing in his laboratory silently

can unleash unimagined dynamics. World-shaking changes rarely begin with muscle power. They often start out unremarkably, with small details. A small marble can trigger a hammer. One individual’s idea can, once implemented, set forces into motion that duplicate the strength of the human body. This all began with the first tools, with the hand axe and the lever, and continued all the way to modern high-performance batteries, construction machinery and supersonic aircraft. Incidentally, when Alfred Nobel invented his explosive, he called it dynamite, derived from dýnamis, or force, as we have seen above. The term dynamics, with its positive connotation, and the explosive dynamite have the same etymological root.

#2
FORCE THAT DUPLICATES ITSELF

The ball strikes another ball, and it strikes two more balls. The track splits, setting other marbles rolling everywhere, they fall with a clatter into shafts, launching new balls. The background noise intensifies, bells ring, tools tap, triggers click.

Without a doubt, when everything starts to move, when forces collide, there is a core of something destructive inside. Or at least disruptive. Explosions with a huge bang are not required. It is definitely enough if things get a push. Hydraulics are a very interesting image in this regard. At first glance, very little seems to be happening. This is no smoking or banging – nonetheless enormous forces are set in motion. Hydraulic systems often carry out core tasks in industry when the work involves production, movement or energy, even though they seem comparatively unremarkable.

In fact, many groundbreaking inventions involve the application of pressure and objects set in motion. The printing press, the automobile and the elevator. But that is only one side of the coin. These inventions were revolutionary because they had social relevance, which acquired a dynamics and a force that surpassed their own movements many times over. Book printing revolutionized communication and education, and the car our transportation. The elevator changed our cities and thus our coexistence. One can become giddy at the thought that, at this very moment, billions of people are in motion,

coming into contact with things, exerting force. It is really no wonder some people feel that everything is moving faster. No wonder people increasingly feel they are under pressure.

#3
ARE WE GETTING ROLLING OR ARE WE BEING DRIVEN?

On the track, the movements have multiplied in such a short time that it is impossible for the human eye to capture everything. Marbles are rolling everywhere. Devices are moving, and balls are making intricate runs, triggered by collisions, seesaws or elevated platforms.

Everything is moving faster. Letters once traveled for days or weeks. Electronic mail wants an answer in a few seconds. Engines bring us around the world in no time at all. Machines are taking over housework. And, nonetheless, many people feel they have less time.

Are we dynamic? Or are we the slaves of time?

Time researchers explain the phenomenon this way: When the smartphone rings, an email pops up, or the next caller is waiting during a telephone conversation, we get the urge to respond. Inventions that were supposed to make us more flexible, agile and dynamic actually do the opposite: They take up our time because they draw new lines. Suddenly everything is measured, clocked and budgeted. You watch how the ball immediately hits the next mechanism in the track, and you cannot stop it.

In his 1934 book, “Technics and Civilization,” sociologist Lewis Mumford called the clock “the prototype of all machines” and dated the beginning of the modern age to the invention of the clock. Time was relative before that point. But suddenly it was being measured exactly.

The term “dynamic” has recently been suspected of being a buzzword, a euphemism for the dissolution of boundaries. Are people who call themselves dynamic really just “self-exploiters” since there are suddenly no limits in force? Not having any time has become a status symbol. Anyone who has no time is important. For years, the time researcher Karlheinz Geißler has preached: “We have unlearned the practice of doing nothing.” Human beings can no longer stand still. They are constantly in motion.

#4
DYNAMICS IS A QUESTION OF POINT OF VIEW

And suddenly everything is quiet again. All the balls have reached the end of their track, have dropped in holes or have rolled out. All of them except for one. Our very first ball keeps rolling determinedly on its way. Click-clack-rrrrr.

Everything is going faster. That is one view of things. Others involve taking a step back, and considering the entire marble run from a distance. The American economist Robert Gordon, known for his prediction of “the end of growth,” believes that the 21st century is actually not as fast-moving as many believe. The revolutions of one hundred years ago were much more serious, he says. Society was changed by electricity, cities by lighting and elevators, transportation and industry by the internal combustion engine. Gordon has no doubts about either the innovative capacity or the dynamic character of humanity. He just posed this provocative question at a TED Talk in 2013: “Would you rather do without a flush toilet or Facebook?”

When railroads, the automobile and the airplane were invented, the entire society was catapulted from walking speed to airspeed within a few decades. We have hardly moved faster than that since then. Even back in the 19th century, there was already panic about change, fears about the dissolution of boundaries, and hysteria about high-speed insanity. People walked with turtles in the street to show their preference for a slower pace. In the early days of civilization, humanity made the transition from a hunting to an agricultural economy. And now the invention of email is supposed to throw us off the track? Putting it soberly, how many professions have actually changed radically in the last ten years? Perhaps the answer already lies in the question: A little less excitement would do us some good.

#5
ON THE ENERGY OF INNOVATIONS

Our ball goes on to a fork in the track. The path that it now takes is not, strictly speaking, an accident. But the nuances are decisive. The force with which its rolling was initiated. The unintentional, imperceptible spin imparted by the initial thrust. One path is taken, the other is ignored.

Innovation lives on speed, people like to say. If you take a closer look, the opposite becomes apparent. Innovations do not come overnight. The forces that develop them tend to emerge slowly. That is why the famous “disruptive,” that is, revolutionary, technologies become hazards. The reason: The powers-that-be see them – and they still ignore them.

Early in the 2000s, the Japanese company Fujifilm and the U.S company Kodak were about the same size and the uncontested market leaders in the field of photographic film. Both of them made about two-thirds of their revenue with photographic film. Then the market for film began to collapse. Fujifilm and Kodak both saw their existence threatened. The two responded – in different ways. Fujifilm subjected its portfolio to a critical review and considered the question: Can we transform our current knowledge into entirely new technologies? From the manufacture of film, the company had acquired great deal of knowledge about chemical processes such as surface chemistry and anti-oxidation agents. The company decided to bet on entirely new fields: pharmaceuticals, cosmetics, and semiconductors, along with medical technology, industrial x-ray systems and bio-imaging. Kodak decided to put more resources into its core business. Today Fujifilm has a revenue of 20 billion euros and a high growth rate. Kodak found delayed salvation in the printing business and makes one-tenth the revenue of its former rival.

The comparison makes this episode especially impressive. But it is not an anomaly. In the course of their histories, numerous companies have had to reinvent themselves again and again. Dynamics can sometimes mean not simply resisting the many forces around us, but instead perceiving them early and letting them give us a little push. Absorbing energy so we can use it to grow. That brings us back to physics and Newton: the principles of inertia, action and reaction: “If a force acts upon a body, it is accelerated in the direction of the force.”

#6
SMALL IDEAS BRING ABOUT GREAT ONES

Our ball has arrived just in front of the track’s end. Once again, it starts a wheel turning by rolling through it, which drives a fairly large gear, which in turn drives an even larger gear. And then it rolls out.

The details are decisive.

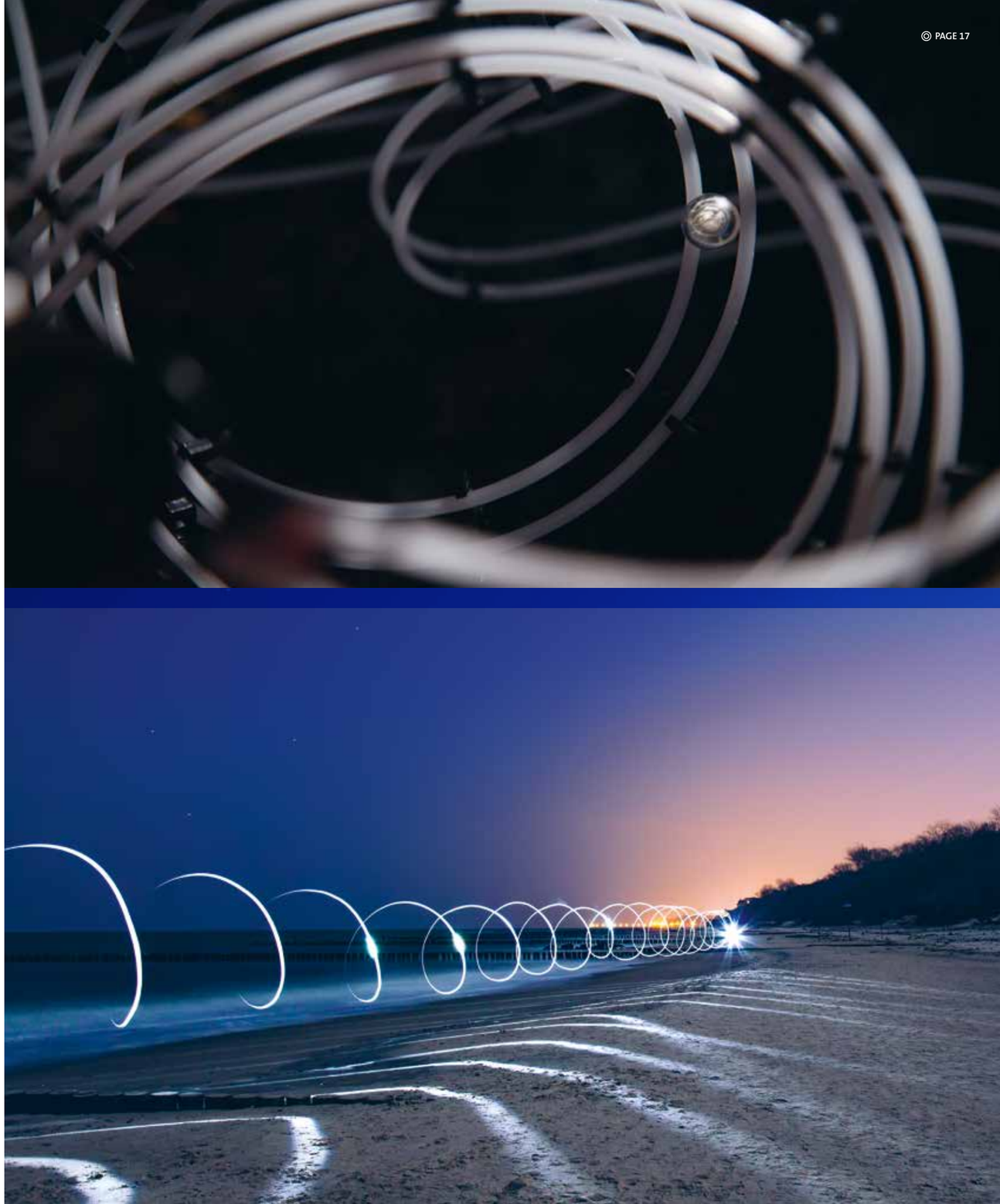
Details such as a tiny seal, for example. A part that determines whether a powerful engine actually functions as it is supposed to. When huge forces act on us or set machines in motion, when enormous pressure is generated – then a small detail, a small seal, can determine whether this force actually arrives where it belongs – or whether it fizzles out and leaks away.

Small matters are decisive.

If dynamics is such a multilayered term, then we can reflect on what else it may mean. Not just “speed” and “the dissolution of boundaries,” but the science of force. The science of sound intensity. And this in turn means that it is up to us to recognize and control the forces and strengths around us. That is what should do.

Everything starts in the mind. And everything ends in the mind.

We have learned that time is a matter of the mind. The decision on how agile and dynamic we are is also made in the mind. And the power of ideas can develop greater dynamics and bring about more change than dynamite does with an explosion. The bottom line: That is an encouraging thought. We have all this in our own hands. ©



5 QUESTIONS for

JOEL JOHNSON

Global Vice President
Mobile Machinery Sector

After several years of crisis, the market for construction and agricultural equipment is becoming more dynamic. Manufacturers are focusing on reductions in lifecycle costs. Joel Johnson, who is responsible for Freudenberg Sealing Technologies' global business in mobile machinery, explains how today's sealing technology can contribute to this outcome.

1 THE WORLD'S POPULATION IS GROWING, AND MORE AND MORE PEOPLE NEED FOOD AND SHELTER. DOESN'T THAT CREATE BRIGHT PROSPECTS FOR THE MANUFACTURERS OF CONSTRUCTION AND AGRICULTURAL MACHINERY?
That's correct long-term. But in the short- and medium-term, other factors determine how much mobile equipment is built: For example, the demand for construction machinery depends heavily on the degree to which the public sector invests in infrastructure. That is why we are looking at rather moderate growth of 2 to 3 percent annually in coming years in Europe and North America. Sales in China have declined sharply, but we see them gradually recovering. We expect the greatest growth in Asia and the Middle East, where major infrastructure programs have been launched.

"LIFE-EXTENSION MEASURES"

2 BUT THERE IS OVERCAPACITY AT THE MANUFACTURERS CURRENTLY. WHAT DOES THAT MEAN FOR YOUR BUSINESS?
Competitive pressures have sharply increased in both construction and agricultural equipment. This is also true for many of our customers' clients. Let's take farmers, for instance. Thanks to today's agricultural technology, harvests are better than ever. As a result, the prices for many agricultural products are very low. This reduces the readiness to invest in new machinery. The manufacturers of mobile machinery are reacting by stressing the "total cost of ownership" (TCO) instead of the purchase price. That's good for us. The reason is that lifecycle costs can be reduced with high-quality sealing systems. On one hand, they improve the efficiency of the powertrain, reducing fuel costs. On the other hand, they extend the life of the equipment. In cooperation with our customers, we've developed seals that withstand more than 18,000 operating hours.

3 LONGER MAINTENANCE INTERVALS DUE TO HIGH-QUALITY SEALS – IS THIS MAINLY A QUESTION OF MATERIALS?
We must continually improve designs as well as materials. And naturally our material expertise plays a decisive role. In some cases, our customers have extreme requirements, perhaps relating to temperature specifications. Manufacturers do not know in advance whether an excavator will be used in the freezing cold of Siberia, African heat, or a humid rain forest in Malaysia. Since different seals cannot be used based on regional usage, they prefer to play it safe. New materials can continually expand the limits of use. For example, the new polyurethane AU 30000 has a temperature range of -35 to +120°C (-31 to +248°F).

4 ON THE TOPIC OF POWERTRAINS, IN RECENT YEARS, THE EMISSIONS LIMITS FOR MOBILE EQUIPMENT HAVE TIGHTENED SIGNIFICANTLY. HOW IS THE INDUSTRY REACTING?
Basically all the new machinery in Europe and in the U.S. now meets Stage IV limits. The exciting question is where and to what degree do other regions follow suit. In China, air pollution is a major issue. In these situations, countries will converge. But what about markets such as India or Iran? In any case, stricter limits are having a positive impact on Freudenberg Sealing Technologies: On average, we supply more seals to powertrains that meet Stage IV than to Stage III systems.

5 WILL WE ALSO SEE A TREND TOWARD ELECTRIFICATION IN MOBILE MACHINERY?
I think this depends on the area of application. Electrification certainly lends itself to industrial trucks. They are often operated in enclosed spaces and, in any case, need additional weight so they don't tip over with full loads. In the future, it can be the battery or a fuel-cell assembly. The situation is different for machinery in agricultural use. These machines are mostly operated over long periods at a constant speed, far from any infrastructure. Here an efficient diesel engine will usually be the best choice. In the smaller construction machinery used in urban environments, a diesel-electric powertrain could definitely make sense. The diesel engine then runs solely as a generator at a constant rotational speed, which reduces the noise level considerably. In some applications – such as a classic excavator – the load fluctuates quite substantially during operation. Here it could be helpful to supplement the internal combustion engine with a hybrid system. You could use the hydraulic system for this, which is on board anyway. A hydraulic system almost always comes into use as the drive for work machines. That is the only way they can transmit powerful forces efficiently. ◎

PLAY IT AGAIN

It’s that time again every three years: The entire construction machinery world gathers in Las Vegas for the industry’s largest trade fair on the North American continent. Since no heavy equipment can do without hydraulic drive technology, the International Fluid Power Exposition (IFPE) takes place in parallel, and suppliers such as Freudenberg Sealing Technologies exhibit their solutions there.

Men and women in business attire are scattered among the tourists. You quickly realize that they didn’t come here for the shows or the gambling. Las Vegas, the world’s entertainment capital, also ranks as one of the most important trade fair venues in the United States. One event is the construction machinery fair CONEXPO-CON/AGG, which is held every three years jointly with the International Fluid Power Exposition (IFPE). Their time came around again in March. Nearly 3,000 exhibitors showed off cranes, excavators and mining equipment, along with the components that ensure that these imposing machines function reliably. At the IFPE, where Freudenberg Sealing Technologies was an exhibitor, the focus was on fluid technology, power transmission, powertrains and their control. Since 2002, CONEXPO-CON/AGG and IFPE have been held as parallel events here. Innovations for the future were displayed in a 7,000-square-meter space. There were also dozens of forums where experts shared their views.

This year’s IFPE was a great success, according to IFPE Director John Rozum. “The industry’s economic downturn is a challenge. But I’m confident that we’re now moving in the right direction.” Infrastructure is now highly valued, which is a reason for optimism, Rozum said.

Freudenberg Sealing Technologies also presented dozens of innovative components and solutions at IFPE. They make it possible to operate machines under extreme conditions such as severe temperature fluctuations and high pressures with longer service intervals while reducing fuel consumption and emissions.

REMOTE-CONTROLLED BULLDOZER

The Internet of Things is making its way into construction equipment just as it is into other fields. Force transmission and even comfort functions are increasingly digitally controlled. Operators can wirelessly retrieve the generated data – for example, regarding the machine's actual utilization level. Caterpillar was not just using the IFPE to introduce new excavators, wheel loaders and other equipment. The company also demonstrated how machines of this kind can be operated over the Internet. From the company's trade fair stand, it was possible to control a model D8T bulldozer at the Caterpillar headquarters 1,679 miles away.

Remote control using the "Cat Command" system offers two different operating interfaces. For example, the portable operating console can be used when the machine is in sight. Or the control takes place via an ergonomically optimized station at any location, provided that the machine is equipped with a "Vision System." In this way, the operator can always work from a place where he is completely safe.

OVER HILL AND DALE

Today in mud, tomorrow on bedrock, sometimes even on swampy ground: Construction machines are increasingly equipped with a system that can vary the air pressure in their tires, so they can perform their heavy-duty work on different types of ground. Until now, standard seals based on polytetrafluoroethylene (PTFE) ensured that the air stayed within the system. But at high pressures, this type of seal could leak. Freudenberg Sealing Technologies presented an alternative at IFPE 2017: a seal with two seal lips that was developed especially for use in tire pressure control systems.

The seal, which is marketed under the name "Central Tire Inflation Seal (CTI)," keeps transmission oil away from the line that carries air to and from the tires. This patented solution can improve tire traction by up to 20 percent, thus reducing fuel consumption by 10 percent. The adjustment of the tire pressure also leads to a 20 percent reduction in tire wear.

NOT A TOY
Driverless construction equipment from Caterpillar can be controlled from anywhere in the world.

PRINTED IN CINCINNATI
In just five hours, a complete cab for an excavator was produced from glass-fiber-reinforced plastic.

DO ONE WITHOUT NEGLECTING THE OTHER

Heavy loads, constantly changing speeds, easy maneuverability. Some demands on the construction machinery industry never change. But the powertrain technology that fulfills these needs is continually improving, as ZF Friedrichshafen showed at this year's fair. The supplier presented its "cPower" continuously variable transmission. It operates with a power splitter that splits the torque. One portion is transmitted hydrostatically and another operates mechanically with especially high efficiency. This reduces fuel consumption by up to 30 percent.

Hydrostatic force transmission has many advantages in construction machinery: Since it does without a mechanical connection between the engine and driveline, there is no wear even with heavy loads. In addition, the machines do not have to stop when they shift from forward to reverse. The mechanical power transmission also saves energy. With the cPower system, it takes over part of the work as soon as the engine starts up.

AN EXCAVATOR FROM A PRINTER

In his book "The Zero Marginal Cost Society" economist Jeremy Rifkin attested to the potential of 3D printing to bring about a new industrial era. At the CONEXPO-CON/AGG and the IFPE, visitors were able to inspect the first excavator built with additive production techniques. A consortium of companies, universities and government agencies worked together on the project. It was directed by three research groups from Georgia Tech, the University of Illinois and the University of Minnesota (USA). 3D printing did not produce each of the excavator's components but rather three large component assemblies: the cab, the excavator arm and the heat exchanger. New technologies came into use that, for example, allow the production of extensive metal parts with these methods. The cab is made of carbon fiber-reinforced plastic, which is also due to be processed with an additive approach.

TAKING IT LIGHTLY

This is urgently needed wherever there is hydraulic pressure: an accumulator, sometimes known as a hydraulic accumulator. It doesn't just serve as storage for pressure equalization. It also dampens vibrations in the system.

Diaphragm accumulators are frequently used in construction machinery. In order to store high pressures, the standard version of this type of accumulator is made from strong, heavy materials. At the IFPE, Freudenberg Sealing Technologies displayed a hydraulic accumulator made of aluminum.

The two halves of the accumulator's housing are bonded by means of electromagnetic pulse welding. This innovative welding process involves one housing half receiving a pulse from a magnetic field, forcing it into a collision with its counterpart. The kicker: In the very same production step, the gas-carrying half of the accumulator is filled with the nitrogen necessary for its operation. So it is ready for installation when it is delivered. This saves the machine manufacturer installation time.

STAYING CLEAN

Starting in 2020, even stricter exhaust gas regulations are due to take effect. "Stage 5" of the mobile machinery limits is expected to further decrease particulate emissions. At the CONEXPO-CON/AGG, John Deere Power Systems was already displaying its first diesel engines that meet the new stage of emissions restrictions. The engines are not only equipped with a new catalytic converter technology. They are also designed for improved power delivery, even when the machines are operated at high altitudes with low oxygen content in the intake air. Thanks to a new exhaust gas post-treatment technology, the engine has turned out to be much more compact, and the required installation space has declined by 39 percent. Its weight is down 57 percent. Since Europe's standards are not in force everywhere, the adaptation of new engines to local requirements is becoming increasingly complex. John Deere intends to counter this trend with an integrated emissions control system. A modular approach to the system's construction is expected to make it possible for machine manufacturers to respond flexibly to the different requirements.

LESS FRICTION, GREATER EFFICIENCY

In the auto industry, Freudenberg Sealing Technologies has already been successful with Levitas, a transmission seal that greatly reduces friction, and Levitorq, a low-friction thrust washer. At IFPE, for the first time, the supplier has shown how this technology can be transferred to work machines. The reduction of fuel consumption is a key issue in this sector as well. Studies show that seals can make a major contribution in this area. For example, one quarter of the total lost mechanical output in automatic transmissions can be solely traced to seals.

Levitas is based on a simple idea: During operation, the seal floats on a hydrodynamic film of oil that it produces itself. This reduces friction by up to 70 percent. The Levitorq thrust washer also works with a hydrodynamic oil film. Thrust washers are traditionally produced from metal. For the first time, Freudenberg has developed a lighter alternative made of plastic.

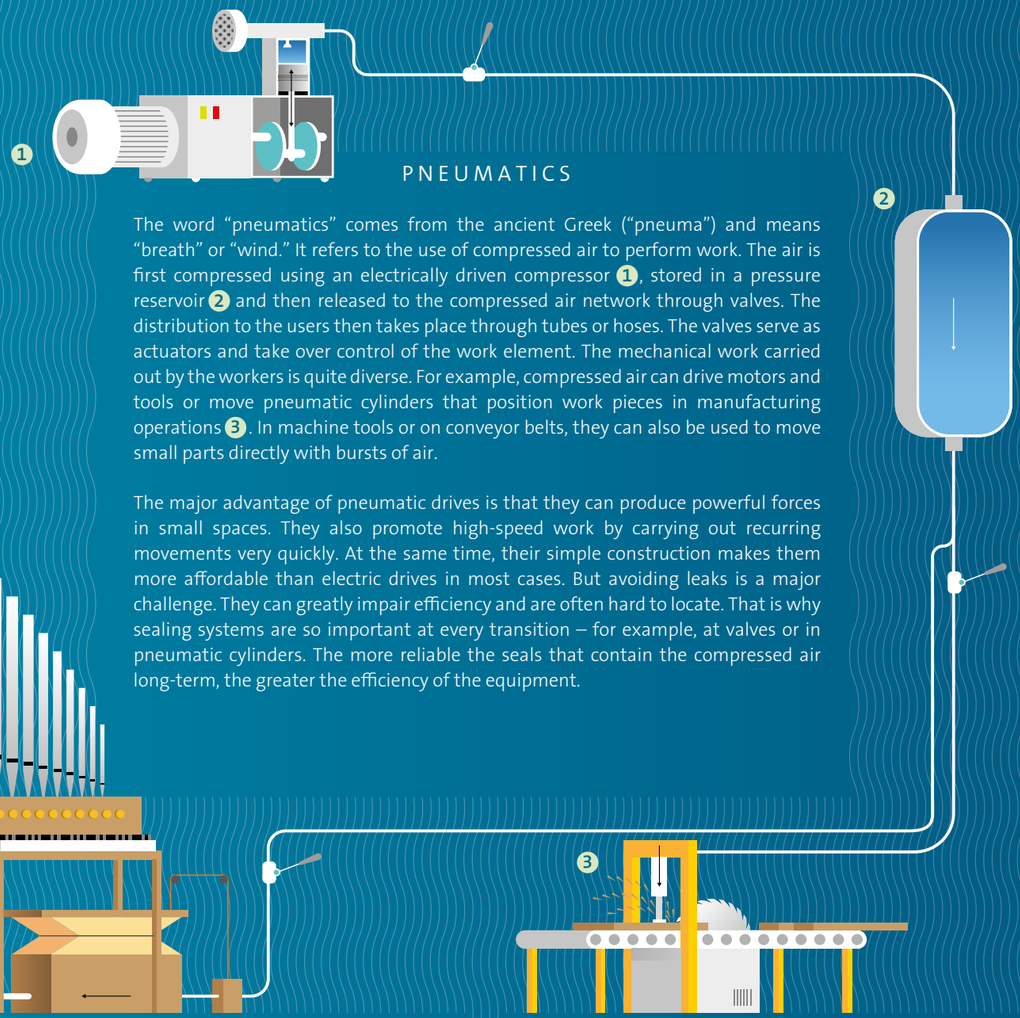
NEW FROM THE MATERIALS LAB

Even the best seal is only as good as its material. This is especially true when it is exposed to high temperatures and chemically aggressive media – such as saltwater – which is normally the case with construction machinery. At IFPE, with a new polyurethane, Freudenberg Sealing Technologies showed how top scores can be achieved for durability.

The material "94 AU 30000" has shown much greater resistance to temperature fluctuations and synthetic hydraulic fluids than other polyurethanes. If the material is used in combination with mineral-based hydraulic fluids, the permissible temperature range runs from -35 to +120°C (-31 to +248°F). In addition, the new polyurethane demonstrates high stability under pressure. Intensive comparison tests, in which pressure and other factors varied, show that seals made of this material show no signs of wear even when conventional seals are already failing. ◎

ON YOUR MARK, GET SET … POWER!

Under high pressure, fluids, meaning gases and liquids, can be used to transmit powerful forces. As compressed air or hydraulic fluids, they perform mechanical work in cylinders or rotating assemblies. But how exactly do pneumatic and hydraulic systems function?



PNEUMATICS

The word “pneumatics” comes from the ancient Greek (“pneuma”) and means “breath” or “wind.” It refers to the use of compressed air to perform work. The air is first compressed using an electrically driven compressor 1, stored in a pressure reservoir 2 and then released to the compressed air network through valves. The distribution to the users then takes place through tubes or hoses. The valves serve as actuators and take over control of the work element. The mechanical work carried out by the workers is quite diverse. For example, compressed air can drive motors and tools or move pneumatic cylinders that position work pieces in manufacturing operations 3. In machine tools or on conveyor belts, they can also be used to move small parts directly with bursts of air.

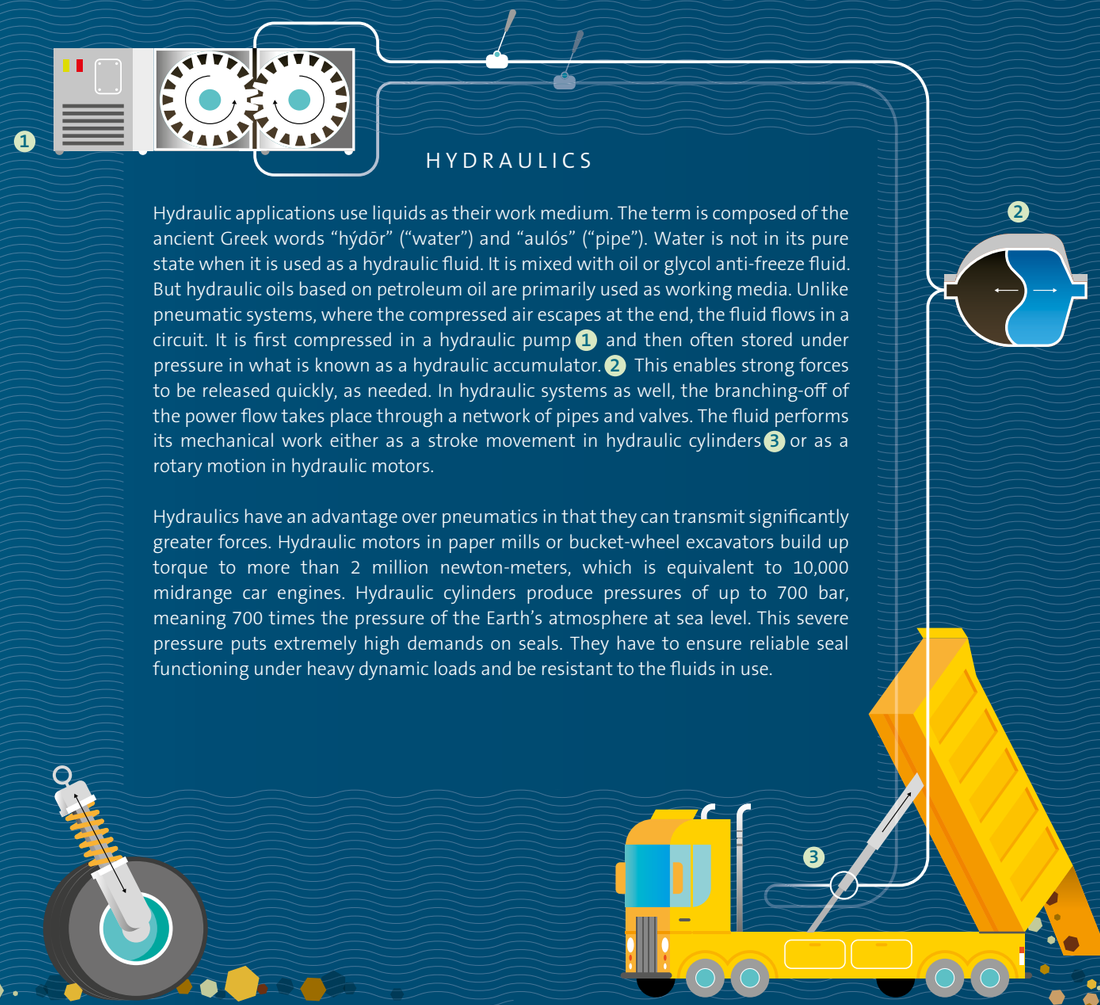
The major advantage of pneumatic drives is that they can produce powerful forces in small spaces. They also promote high-speed work by carrying out recurring movements very quickly. At the same time, their simple construction makes them more affordable than electric drives in most cases. But avoiding leaks is a major challenge. They can greatly impair efficiency and are often hard to locate. That is why sealing systems are so important at every transition – for example, at valves or in pneumatic cylinders. The more reliable the seals that contain the compressed air long-term, the greater the efficiency of the equipment.

ORGANS

In church organs, compressed air serves as the so-called “organ wind” and enables their pipes to produce notes. Rotating blade wheels compress the air in centrifugal blowers, and valves regulate the flow rate of compressed air to the bellows. Unlike industrial applications, the wind channels distributing the compressed air are made of wood.

MACHINES AND INSTALLATIONS

Pneumatic cylinders are an often-used machine element in plant equipment. They primarily produce linear motion, but they can also carry out pivoting movements with the help of a gearbox. In manufacturing processes, pneumatic cylinders position and secure work pieces within processes or divert them onto longer conveyors.



HYDRAULICS

Hydraulic applications use liquids as their work medium. The term is composed of the ancient Greek words “hýdōr” (“water”) and “aulós” (“pipe”). Water is not in its pure state when it is used as a hydraulic fluid. It is mixed with oil or glycol anti-freeze fluid. But hydraulic oils based on petroleum oil are primarily used as working media. Unlike pneumatic systems, where the compressed air escapes at the end, the fluid flows in a circuit. It is first compressed in a hydraulic pump 1 and then often stored under pressure in what is known as a hydraulic accumulator. 2 This enables strong forces to be released quickly, as needed. In hydraulic systems as well, the branching-off of the power flow takes place through a network of pipes and valves. The fluid performs its mechanical work either as a stroke movement in hydraulic cylinders 3 or as a rotary motion in hydraulic motors.

Hydraulics have an advantage over pneumatics in that they can transmit significantly greater forces. Hydraulic motors in paper mills or bucket-wheel excavators build up torque to more than 2 million newton-meters, which is equivalent to 10,000 midrange car engines. Hydraulic cylinders produce pressures of up to 700 bar, meaning 700 times the pressure of the Earth’s atmosphere at sea level. This severe pressure puts extremely high demands on seals. They have to ensure reliable seal functioning under heavy dynamic loads and be resistant to the fluids in use.

SHOCK ABSORBERS

Hydraulics operate passively in the shock absorbers of powered vehicles. In the suspension system, telescopic shock absorbers soften the vibrations of the vehicle structure. In this system, a piston rod has been extended into an oil-filled cylinder. If the piston moves downward, the oil flows through narrow channels and valves and builds up resistance to create the damping effect.

DUMP TRUCKS

Hydraulic cylinders are used to transmit massive forces in agricultural and construction machinery. For example, with the telescopic rams of dump trucks, they move troughs loaded with bulk material upward during discharge, functioning as a linear hydraulic motor. The pressure can also be distributed to hydraulic wheel hub motors to power additional axles on rough terrain.

THE GREEN DAUGHTER OF THE DESERT

Las Vegas is reinventing itself – as a metropolis of sustainability. But can a commitment of this kind work in the middle of the desert? The water supply in particular remains a touchy issue for the fast-growing city despite major investments in a modern water infrastructure and increased efficiency.

In 1974, Pat Mulroy arrived in Las Vegas as a 21-year-old student of German literature. She took a room in a small hotel on Las Vegas Boulevard, south of the large casino hotels, with a view of the Mojave Desert. “I thought I was on Mars,” Mulroy recalled. But the swimming pool in front of her hotel was lit up in blue light. Fountains burbled in front of the casinos. Walls of water sprayed over golf courses. She found extravagant luxury amid the shimmering heat. “No one talked about water problems back then.” The residents of Las Vegas ignored the realities of their community, which lies in one of the driest areas of the continent.

Today Pat Mulroy is on the law faculty of the University of Las Vegas and specializes in environmental and water issues. Over a period of 25 years, from 1989 to 2014, Mulroy created and led the South Nevada Water Authority, the first comprehensive water agency for the region. She battled against the Mafia, real estate sharks, and bureaucracy – along with the local population at times, her critics say. The story of this high-powered woman, who was born in Frankfurt and grew up in Wiesbaden as the daughter of a German citizen and an American Air Force service member, ran parallel to the rise of the city, which grew to become a desert powerhouse contrary to all natural laws. Today it is fighting to survive – and to become a model – with the most advanced methods at its disposal.

ARTIFICIAL GREENERY

Ever since Las Vegas experienced an historic water shortage last year, more and more people are thinking like Mulroy. One example: The miles of real grass that have been transformed into artificial lawn in Las Vegas could extend once around the world. Las Vegas pays $20 for every square meter that its residents transform into artificial grass or desert flowers on their own property. The city administration and the large casinos on the Las Vegas strip have proclaimed sustainability on their advertising banners and websites. But there is a major, difficult-to-answer question behind all the programs: To what degree can an artificial oasis actually grow sustainably? Mulroy is optimistic: “Here we can move mountains together.”

Upon a closer look, the picture is more complicated. Las Vegas is surrounded by mountains that still account for four-fifths of America’s gold production. Gold miners once made Nevada famous, and gold-seekers were the people who decimated the original inhabitants after the official discovery of Las Vegas Valley about 200 years ago, and turned this desert site into a gambling metropolis. The region’s revenue is now $100 billion, and the sparkling valley is now one of the fastest-growing urban centers in the U.S. Over the past two decades alone, the population of greater Las Vegas has more than doubled, from 800,000 to more than 2 million inhabitants. They are joined by more than 40 million visitors a year. The bulk of the largest hotels are in the area around the strip, still the lifeblood of the state despite declining gambling revenue.

But Nevada is not an optimal location for growth. Aside from metals, it hardly has any natural resources. The Colorado River flows by Las Vegas southeast of the city; it was blocked by the Hoover Dam, which was completed in 1935, becoming a source of water and energy. Lake Mead is the largest reservoir in the United States and, at 640 square kilometers (250 square miles) it is significantly larger than Lake Constance. The energy generated by the dam's hydropower plant mainly flows to other states. Nevada gets its resources from its neighbors Utah and California, which send oil and natural gas through pipelines into the desert state.

Natural gas keeps the power plants running that make light and life possible in the oasis in the first place. On average, a Las Vegas resident consumes twice as much electricity as a Berliner, which makes it about average U.S.-wide. Nonetheless, power plants in Nevada cannot generate enough electricity for the state's customers. They have hooked up to electric grids in Utah, Arizona and California. In all, Nevada only produces one-fifth of its energy using alternative sources.

"When I look out the window here in my office at City Hall, I see solar trees," said Betsy Fretwell. "You don't find them anywhere else in the U.S." Fretwell is the city manager of Las Vegas and its top official after the mayor. She is proud of the new, silvery metal posts with solar panels, which now supply the electricity to light up the famous "Welcome to Fabulous Las Vegas" sign. Parks, community centers, fire departments and administrative buildings – Fretwell has had everything under the city's control converted to electricity from the desert sun. This has cost $15 million so far. "We are saving $5 million a year with it. That is 1 percent of my total annual budget," she said. "If you invest wisely in energy efficiency, you save money in the end."

SUSTAINABLE CASINOS

In the future, Fretwell believes that Las Vegas "will see a highly diversified market of energy sources. More solar, thermal, hydro. And everything will be cheaper." She plans to work even more closely with the energy rebels among the casinos. After all, this ultimately involves a new narrative. "We are 'Sin City,' and that is good for tourism. But many people overlook the fact that we are managing the environment efficiently." Three of the largest players on the strip – MGM, Caesars and Wynn – have been tinkering with the story of the new Las Vegas for years. Their companies have their own sustainability departments. They build solar systems on their roofs, screw LED lights in their ceilings and publish comprehensive reports. "This is no accident. It's good business," said Cindy Ortega, the Chief Sustainability Officer at MGM, recently in an interview. Meanwhile, rival Caesars points out that it pays employees extra vacation time if they can show that they are saving energy and water at home.

For all the happiness about the new sustainability, the water shortage remains. It is the city's sore spot. All the green projects are of little use if rain and snow never arrives, the level of the Colorado falls, and Lake Mead shrinks from a huge reservoir to a lukewarm bathtub. In all, a total of seven U.S. states and Mexico depend on the water of the mighty river. In 2012, they all reached an agreement on who will get what amount of water – and when they won't get any more. The situation had reached this point last year: A gigantic "bathtub ring" generated headlines for Lake Mead around the world. After 16 years of more or less continuous drought, the level of the reservoir was at 1,074 feet, or about 327 meters, a record low.

"The magic boundary is at 1,075 feet. Below that, it is a crisis," said Mulroy. Starting at 1,025 feet, the U.S. Interior Department takes control. At 900 feet (274 meters), it is the end – the turbines remain shut down, and no one on the lower course of the river can take any water. But things have not yet reached that point. Plenty of precipitation during the winter brought water back into the river. Still, the experts agree: It is not a matter of whether – but rather when – the residents of Las Vegas, Phoenix and Los Angeles will have to look elsewhere for their water. The city is investing in water recycling facilities that are supposed to purify as much water as possible and pump it back into Lake Mead; in new lines, including a pipeline that runs under the lake; in artificial lawn and desert renaturation initiatives; and in plans for a desalinization facility on the coast of Mexico.

125 GALLONS PER DAY

The city's thirst fell by more than one-third between 2002 and 2015 while its population added 400,000 people. A major sustainable success. All the water used in buildings is reportedly now recycled. But too much is still lost outdoors, on golf courses, gardens and farms. From a statistical standpoint, each resident still consumes an average of 125 gallons (470 liters) of water per day – four times as much as a Berlin resident.

Mulroy is optimistic that Las Vegas will find a way to deal with the water shortage: "People here will always come up with solution. If Abu Dhabi and Dubai do it, Las Vegas will do even more." But where will the daughter of the desert get its water if sun and wind aren't able to help, if climate change makes the earth even drier and robs the river of even more water, and the thirst is even greater? Without any hesitation at all, she answers: "We'll look to the sea." ◎

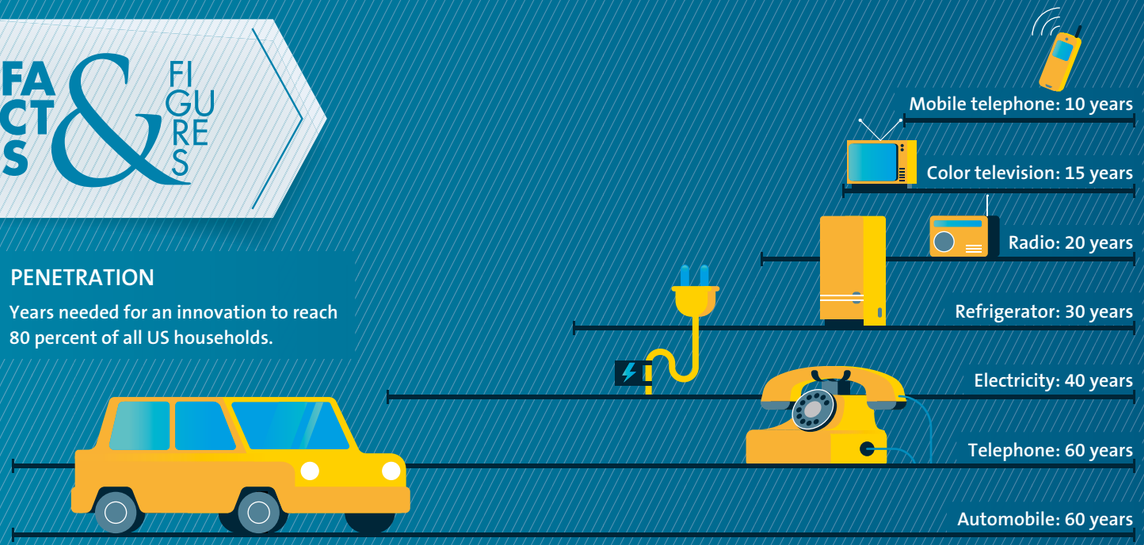
SCARCITY
The water level behind the Hoover dam is falling continually.

EFFICIENCY
Water usage has declined one-third in Las Vegas.

FACTS & FIGURES

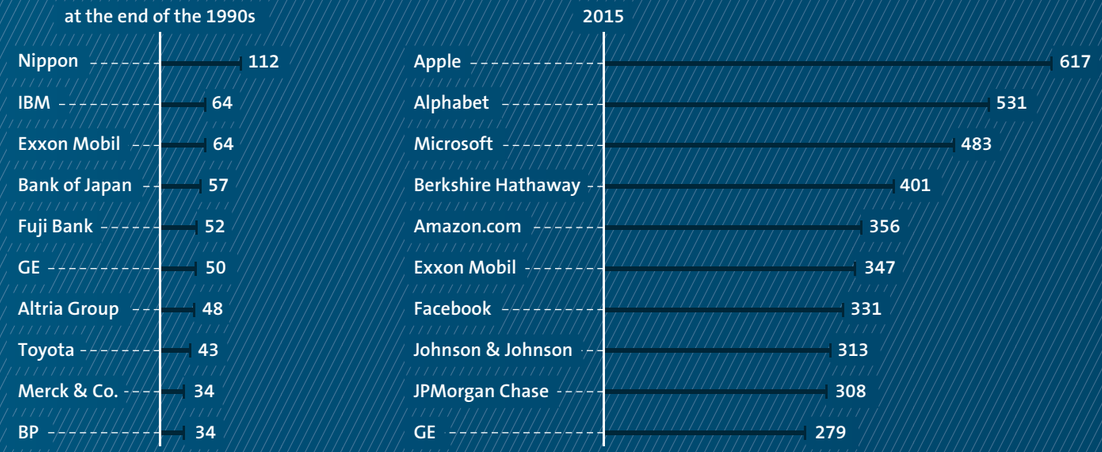
PENETRATION

Years needed for an innovation to reach 80 percent of all US households.



THE LARGEST COMPANIES WORLDWIDE

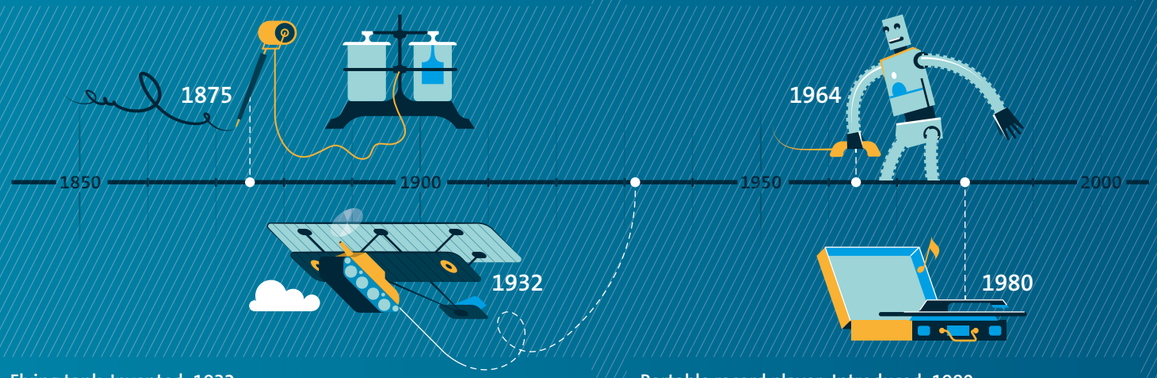
based on market capitalization in billions of dollars



INNOVATIONS THAT WERE AHEAD OF THEIR TIME

Electronic pen. Invented: 1875
No less an inventor than Thomas Edison recognized the advantages of fast, electronic copying, and, with the help of a battery, invented a pen that left impressions in paper that could be copied. It was the right idea but it was too complicated. A short time later, a better solution reached the market: the typewriter.

Robots that answer calls. Introduced: 1964
A machine that picked up the receiver, and ... laid it back down again. That's all the robot could do. In theory it was quite practical, but other inventors were simultaneously working on the answering machine. It could record messages without even removing the receiver.

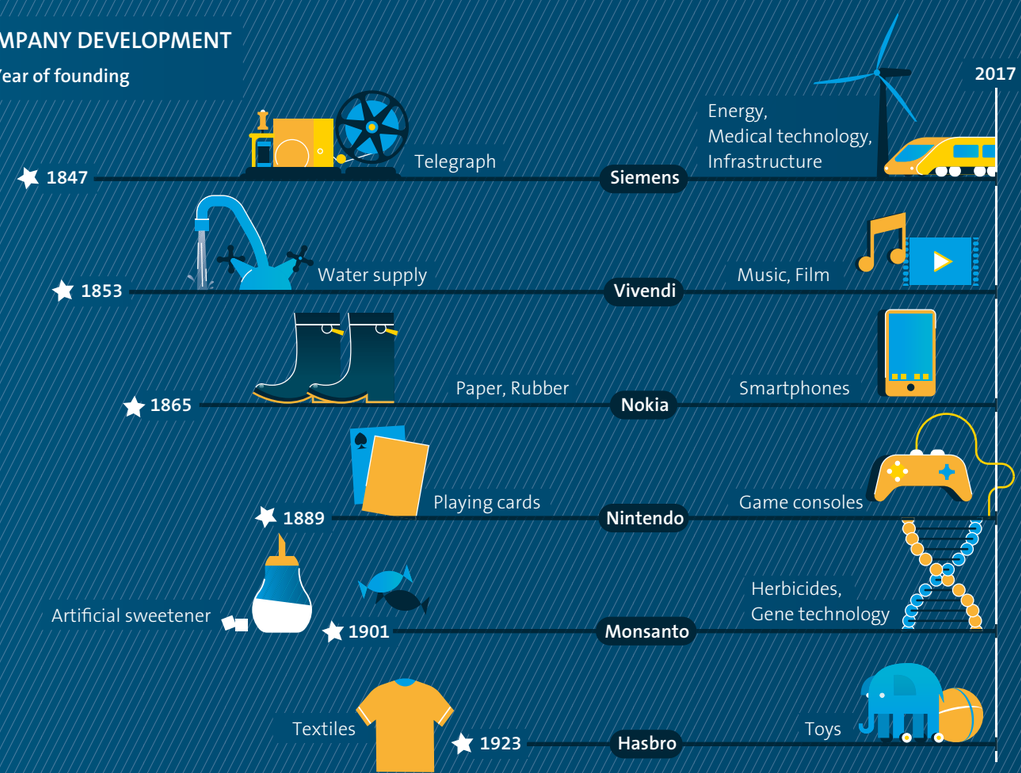


Flying tank. Invented: 1932
„The two most advanced implements of war combined into one!" That's how the advertising posters described it at the time. It turned out that, with the invention of better airplanes, it made a good deal more sense to transport tanks to the area where they would be used instead of flying them there.

Portable record player: Introduced: 1980
What would it be like for people to carry their own music around with them? An ingenious idea. That's what the inventors thought when they developed a portable record player in the 1980s. Unfortunately, cassettes and the Walkman followed shortly thereafter. Today we carry our music around in our telephones.

COMPANY DEVELOPMENT

★ Year of founding



“IF YOU ARE AFRAID TO FAIL, YOU WON’T BE INNOVATIVE”

Many companies like to see themselves as dynamic and innovative – but innovation doesn’t automatically arrive on cue. Dr. Jan Kuiken of Freudenberg Sealing Technologies (FST) and Management Professor Charles O’Reilly talk about the balance between old and new, available and required resources, and the ideas kept in drawers.

MR. KUIKEN, HOW FAR AHEAD CAN SOMEONE LOOK INTO THE FUTURE?
Kuiken: He can look infinitely far ahead, but how relevant is what he sees there? Some time ago, we had a project whose objective was to look 35 years into the future: How is demography developing? What will the main trends be? This was a wonderful experience for writing a science fiction novel. But which of the scenarios from the genre’s great novels actually have any business relevance? A few, at most.

SO LOOKING TOO FAR AHEAD DOESN’T HELP AT ALL?
Kuiken: Sure, it can be very beneficial, but in the real business world, a realistically manageable timeframe is just two to three years. And even that is uncertain. Who predicted the financial crisis of 2008/09? So what we need is both a view of the future and absolute flexibility to make adjustments. In our department, we have now determined that we want to look ahead about nine to ten years.

"LEAD AND DISRUPT" (2016)

Together with co-author Michael L. Tushman, O'Reilly investigates how companies manage a successful balance between their core business and innovation. In doing so, they present a wide variety of examples of successful (and failed) innovation strategies. The business professors' conclusion: Successful innovation is a question of the right leadership, and many of their successful examples point to a great many common denominators. The book is presented as a highly readable combination of research studies and a management guide.

MR. O'REILLY, IN YOUR LATEST BOOK „LEAD AND DISRUPT" YOU VIVIDLY DESCRIBE HOW MANY COMPANIES FAIL AT INNOVATION BECAUSE IT REQUIRES TIME AND RESOURCES.
O'Reilly: Yes. And this is very logical to start with. Many companies feel they are under financial pressure. They think rather short-term. Even investors and shareholders are not necessarily interested in costly experimentation. They can invest their money directly in startups. In addition, successful companies in particular spent a great deal of time and energy in establishing themselves in the forefront of their earlier business field. Why should the company risk its short-term success when its long-term success is not guaranteed in return? A great deal depends on management, on the will to move in this direction.

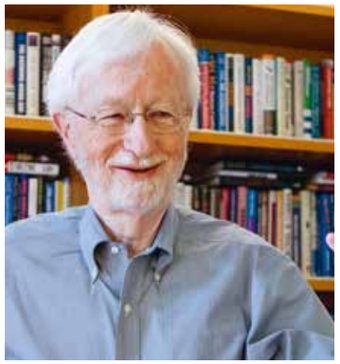
THAT IS ONE OF THE CENTRAL THESES OF YOUR STUDIES: LEADERSHIP IS CRUCIAL. IF YOU WANT TO BE INNOVATIVE, YOU NEED A PERSUASIVE EXECUTIVE AT THE HEAD OF THE COMPANY WHO TAKES THE LEAD.
O'Reilly: But here we are not talking about leadership style, which can take many different forms. We have worked with a great number of companies, and one of them was Cypress Semiconductor, a semiconductor manufacturer. The executive had a rather authoritarian style and handled many things personally. But he encouraged innovation. Another example is DaVita, which was involved with dialysis technology. But it was practically bankrupt at the end of the 1990s. CEO Kent Thiry was an entirely different type of manager, much more accessible, but it was his willingness to experiment that was crucial. I see leadership as the capacity to do what makes the company successful while managing experimentation for the future. DaVita is a comprehensive pharmaceutical company today, and Cypress has founded new startups such as solar cell manufacturer SunPower. In this way, both have developed entirely new fields for themselves.

HERR KUIKEN, DO YOU SEE PARALLELS HERE IN THE WAY THAT FST IS NO LONGER FOCUSING SOLELY ON SEALS FOR LITHIUM ION BATTERIES?
Kuiken: We have had a change in thinking. Until now, we have focused strongly on components, but we are meanwhile increasingly thinking in terms of systems. The knowledge for this is based on our experience with materials, but it goes beyond that – in the direction of electromagnetic shielding, for example. There are questions that we are asking ourselves: How do we bring this to market? What could the future business fields be?

INNOVATION DEMANDS SELF-PERSUASION?
Kuiken: Yes. No inventor who ever took an idea from its nucleus to market readiness would say it was easy.

PROF. CHARLES A. O'REILLY
Professor of Management at Stanford University's Graduate School of Business

At Berkeley and Harvard, taught leadership, organizational demography and diversity, and organizational innovation and change. Today, among other responsibilities, he runs the corporate consultancy "Change Logic" with Michael L. Tushman. It consults with companies worldwide on innovation issues.



MARSHMALLOW CHALLENGE

This has become a popular component of workshops and continuing education courses. Here are the statistics: The towers built by the participants are 50 cm (20 inches) high on average. Kindergartners achieve an average of 75 cm (30 inches), while business students reach only 25 cm (10 inches). The reason: Most of the students waste a great deal of time, at first looking for the most perfect solution analytically, drawing construction plans and discussing the project.

At the same time, self-doubt is always part of the experience. Ultimately, I am entering new territory. It is impossible to see the path in advance. This is a frame of mind. What does the Marshmallow Challenge tell you? It involves groups of people being asked to build a tower out of spaghetti, thread and a marshmallow. And what type of group regularly scores the best? Not the engineers, but rather primary school children. They have the courage to just keep trying. Failure is a learning process. If you are afraid to fail, you won't have the capacity to innovate.

O'Reilly: IBM once found that it had developed but never commercialized 29 technologies that are successful today. The reason: At the time, it lacked a culture that supported innovation. Instead, the departments all ended their development work to protect their profit margins.

ON THE OTHER HAND, PREMATURE DEVELOPMENT MAY BRING YOUR PRODUCT TO MARKET TOO EARLY. IN THE PAST, HAS FST COME UP WITH AN INNOVATIVE IDEA THAT HAD TO LIE IN A DRAWER FOR A LONG TIME BECAUSE THE MARKET WASN'T READY FOR IT?
Kuiken: Levitex is one example. We developed the basic concept ten years ago. But the industry did not yet see the need for it. CO_2 reduction was certainly an issue, but the manufacturers used their own standard solutions to deal with it. Then came the diesel scandal, which reshuffled all the cards. Incidentally, the exciting question is: Which area is developing more rapidly and dynamically: the reduction of pollutants in internal combustion engines – or e-mobility?

FST IS WORKING ON BOTH FIELDS. ISN'T THAT SCHIZOPHRENIC?
Kuiken: No, on the contrary. I always have to think in terms of scenarios. The future is not a straight line. There are always various possibilities. We have to make sure that we have the solutions in our drawer. The crucial job of a research and development department is deciding what fields should be tackled. In the end, our resources are naturally limited.

DR. JAN KUIKEN
Senior Vice President of Technology & Innovation

Has worked at Freudenberg for more than 24 years in various positions, including development management, project management and at the Competence Center. Since March 2016, Kuiken, who holds a doctorate in mechanical engineering, has led Technology & Innovation and has been responsible for tool making at FST.

INNOVATIONS AT IBM

Among other things, IBM developed the first commercial router, but Cisco picked up the idea and propelled it to market leadership. As early as 1996, IBM was aware of techniques to accelerate online applications. It was rival Akami that successfully carried them out.

LEVITEX

The crankshaft mechanical face seal Levitex produces a cushion of air that seals the engine compartment practically friction-free, reducing CO_2 emissions. More on Levitex can be found on page 47.

At FST, we have developed the Innovation Management System for just this purpose. It divides the ideas into categories: “bread-and-butter,” “pearls” and “white elephants.”

O’Reilly: I haven’t heard it put that way before, but I really like it.

YOUR MAIN THESIS IS THAT COMPANIES MUST MAINTAIN A BALANCE BETWEEN SUCCESSFUL PRODUCTS AND NEW PRODUCTS. THE TERM THAT YOU HAVE COME UP WITH IS “AMBIDEXTROUS.”
O’Reilly: The core business and innovation play by completely different rules. Values and conventions that are responsible for making a company a success in its core business become obstacles in the new business. In our studies, the companies that have shown themselves to be successful innovators almost always had a spatial separation between the core business and innovative projects. But, at the same time, there was permeability so the young contenders could benefit from the strengths that they lacked such as sales and accumulated knowledge. Plus an overarching vision and values. This is anything but easy. Personally, I am fascinated again and again at how companies are able to walk this tightrope.

Kuiken: It does a company good to think completely differently once in a while. Most of our innovations are rather incremental. In the case of really radical ideas, we must ask ourselves: Why is this radical? What do we want to do with it? Like the idea of being able to extract all the ingredients for a seal out of a few cubic meters of air.

TO ME THAT SOUNDS VERY RADICAL.
Kuiken: Doesn’t it? When my boss told me about it the first time, I just looked at him in disbelief. But this naturally puts us squarely into a discussion of ecological footprints. With our products, we want to make a contribution with sustainable goods and with materials that can be recycled. Material innovation is very important to us.

O’Reilly: That actually works?

Kuiken: A year ago, it still sounded quite insane. Then we started to do the research and today it already sounds less radical.

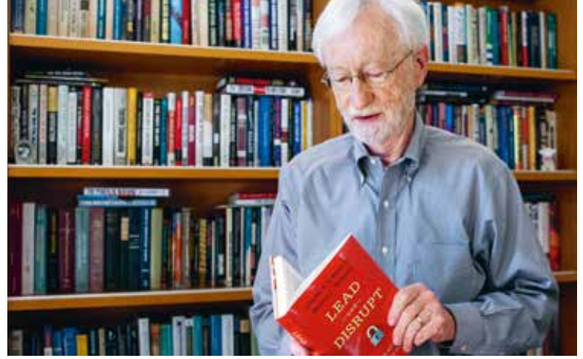
INNOVATION MANAGEMENT SYSTEM

The Innovation Management System (IMS) was introduced at Freudenberg Sealing Technologies in 2012 and is the framework ensuring that valuable ideas are not lost. It received the TOP Innovation Award from the FAZ Institute.

TYPES OF INNOVATION

Innovation research is divided into various areas: Incremental innovation, for example, applies to new processes that are based on earlier knowledge. Substantial innovation means new technologies, while revolutionary innovations can call into question what the company has built up in terms of knowledge and capacity. They change the overall market.

DR. JAN KUIKEN
“The future is not a straight line.
There are always various possibilities.”



PROF. CHARLES A. O’REILLY
“The core business and innovation play
by completely different rules.”

BUT NO COMPANY CAN SUPPORT ITSELF ON RADICAL IDEAS ALONE.
O’Reilly: There are companies that have been very successful at selling innovative ideas when they were not able to execute them themselves. Sometimes a company has the sales structure or the chance to market innovations itself.

Kuiken: Let me stick with this image briefly: If I only have radicals in a chemical process, then I have chaos. But radicals still move around in the system. If I completely forget the system, meaning my own company, then I am heading in the wrong direction. The ultimate goal must always be to move the company forward.

WHEN YOU LOOK AT THE HISTORIES OF SUCCESSFUL COMPANIES, YOU REALIZE THAT MANY OF THEM DON’T EVEN MAKE WHAT THEY ORIGINALLY STARTED OUT WITH.
O’Reilly: The British aviation and auto supplier GKN started out as a coal mining firm. Ball Corp. is a global producer of cans, but one of its main pillars is now in aerospace technology. The list goes on. I admit that I was not familiar with Freudenberg beforehand. The story of a tannery that manufactures seal rings from leather scrap and then makes the leap into new materials is a wonderful example.

SO IS IT POSSIBLE THAT FST WILL NO LONGER BE PRODUCING SEALS IN 50 YEARS?
Kuiken: Yes, it’s possible that we will then be building systems or providing services. Why not? But if we proceed as we have to this point, we will definitely still be around. This conviction is anchored very deeply in the organization. Because we know from our history that we were always in a position to keep going. If you look back 150 years, you see so many crises and revolutions: the oil crisis, the world wars, the technological developments.

RADICALS (CHEMISTRY)

In chemistry, atoms and molecules are called radicals when they have a free electron and, as a result, are mostly quite reactive. At the same time, this often makes them very short-lived. Radicals play an important role in oxidation processes, for example.

O’Reilly: That is very wise. And very appropriate. Incidentally, earlier I mentioned the major crisis at a large company like IBM that has missed out on ground-breaking developments. For the sake of completeness, I have to note that the company got its act together in a very impressive and instructive way. It generates a large portion of its revenue today with services and software – and no longer with hardware.

Kuiken: Now we are back at the start of our discussion: looking ahead is only helpful if we are prepared to adapt. You have to be ready to move in new directions. ◎

Read the entire interview
online at www.fst.de

LONGER LIFE

Rock drills from Atlas Copco work their way through the toughest granite as easily as a do-it-yourselfer cuts through plasterboard. But wear is a major problem in underground mines. Working closely with Freudenberg Sealing Technologies, the company has brought out a generation of equipment that requires much less frequent maintenance.

The large granite blocks in front of the test center's entrance come up to Lars Persson's chest. "The highest Swedish quality," he says with a chuckle. He calls the hard plutonic rock his most important test specimen. Persson directs the development of boring drills at Atlas Copco, the Swedish machine builder. Known as rock drills, they bore holes into stone – large ones with a diameter of several centimeters, which are filled with explosive charges. A controlled ignition is carried out in a half circle of eighty holes – and suddenly the tunnel is four meters (13 feet) longer. That is the current technology for digging a supply tunnel for raw material mining. "In the process, speed is a crucial factor for our customers – the mine operators," Persson knows. And speed above all means power. So much power that rock boring equipment from Atlas Copco cuts through granite like a hot knife through butter. The drill bit hits the stone surface up to 140 times per second with a 25-ton force.

But wear is a certainty wherever raw forces of this kind reign. In just normal operation, all the components of a rock drill are exposed to extreme forces. Special situations come up again and again as well. For example, if the drill bit does not strike stone due to an operating error, the force cannot be reduced – it acts on the machine after the stroke reversal. As a result, the maintenance intervals are short: Until now, a general overhaul has been needed after about 400 hours of operation, which

LONGER-LASTING
The new COP MD20
rock boring drill.

represents about six months of work in underground mining. For the development of a new generation of rock drills, Persson set an ambitious goal in 2011: the maintenance intervals were supposed to more than double to 1,000 operating hours. “In this way, we want to reduce lifecycle costs for operators,” Persson mentions. “Our customers increasingly make their calculations in costs per meter of tunnel or, at a minimum, per hour of operation.” It is no longer enough to simply be faster to stay competitive.

CLOSELY EXAMINED

To reach this ambitious goal, it was essential for developers to proceed along new paths. “We started with a blank sheet of paper and called everything into question,” Persson remembers. Only one thing was clear: The main starting point had to be the seals because they result in reduced efficiency if they are damaged. Leakage in a hydraulic system working under high pressure leads to an insidious deterioration of the ratio between the power utilized and the amount of force at the drill bit. Persson invited the seal manufacturer, which had already worked on the preceding generation, to a workshop.

Gunnar Pettersson, who is responsible for Freudenberg Sealing Technology sales throughout Scandinavia, recalls the situation: “The engineers from Atlas Copco and our developers jointly analyzed all the damage that occurred during operation. That was the only way that we were able to precisely understand the harsh operating conditions and come up with a remedy.” Major stresses in particular act on the piston that drives the drill bit and serves as a damping element when it retracts. In the new machine, known as the MD-20, the bit moves 20 mm back and forth with a frequency of 75 Hertz, while rotating at the same time. Over its required operating life, this produces 540 million movements, which all components must withstand without suffering damage. The metal parts – such as the piston – are made of special steels with especially high strength. “In the past, we had optimized the piston to the point that it held out,” Persson knows. “Now it was a matter of improving the piston seal.” When it came to the wear issue, the engineers discovered that it was the rotation – not the longitudinal movement – that was crucial. “We even surprised ourselves with our analysis. The seal rotates relatively constantly at 300 to 400 rpm,” Pettersson says. Working with the customer, he changed both the product’s method of construction and its material composition. This showed that its operating life could be considerably increased.

TOUGH TESTING

The new development first had to prove itself on a fully automated test stand that Atlas Copco had designed. The rock is only simulated with hydraulic counter-pressure so that various types of rock can be tested virtually. Granite blocks were only used for the final validation of the complete machine. And even that was not enough for Atlas Copco’s series production release. Six experimental vehicles had to prove themselves for a year in real-life applications underground, in Sweden, Spain, Portugal and Australia. After countless hours of testing, it was clear that the new rock drills from Atlas Copco would have double the maintenance intervals of their predecessors. During the fall of 2016, Atlas Copco presented the MD-20, its new rock drill generation, along with a new tunneling machine, at a Las Vegas trade fair that specializes in mining technology. In a parallel effort, the first pilot series samples were manufactured. The first machine that the company sold went to Chile, where it will do its job in a copper mine.

If you ask Persson about the secret of this success, he has a ready answer: “It quickly emerged that taking care of a single component that is critical to success – and not spreading yourself too thin – is the right thing to do.” That doesn’t mean that Freudenberg Sealing Technologies won’t be supplying other seals for new Atlas Copco boring machines. For example, seals ensure that neither drill dust nor moisture can penetrate the housing. That is a way to extend operating life underground since saline water is trapped in many rock layers and is highly corrosive. In all, 30 different seals in every MD-20 ensure that progress is made hole by hole, meter by meter, beneath the earth. ◎

FRICTION-FREE LAUNCH

With its new Levitex mechanical face seal, Freudenberg Sealing Technologies is making the nearly friction-free sealing of crankshafts possible for the first time. The company's Pinerolo plant in northern Italy is preparing for series production. The focus is on the greatest possible automation and integrated quality control.

The small Italian city of Pinerolo in winter. The Cottian Alps rise in the southwest. The nearly 4,000-meter-high Monte Viso is still snow-covered. The air is cold and clear, and the sun shines low in the valley. On the way to Freudenberg Sealing Technologies' Piedmont facility, you have to pay attention. The puddles in the road have frozen, and tires keep losing their grip. There are times when friction is crucial. Yet Freudenberg engineers at the Pinerolo plant are working on ways to avoid friction, not in tires but rather in the engine compartment, at the transition between the engine and the transmission. Friction is undesirable there. It transforms valuable torque into lost waste heat. Pinerolo is the world's first facility where totally friction-free seals are due to be produced in series for crankshafts, starting in 2018. The primary objective of these mechanical face seals, whose trade name is "Levitex," is to cut vehicles' fuel consumption and emissions.

In late 2016 at the Pinerolo facility, Freudenberg Sealing Technologies put a manufacturing line into operation for short production runs of Levitex seals. "We are now working with a major European automaker to develop the seals to series readiness," said Francesco Scarano, who is in charge of research, development and the production launch of the new seals. Since 2010, Freudenberg Sealing Technologies has been involved in intensive research on the new technology. Since January 2016, Scarano's team has been producing prototypes on its own production line to validate its production goals with real components. Now it is primarily a matter of automating production. In all, seven robot arms are in use at the production line's individual stations. "Since the robots always carry out the individual work steps in the same way, the assembly process can be effectively replicated," Scarano said. That is crucial for the rapid transfer of Levitex seal production to other assembly lines. "When we've completed the fine-tuning, we can expand the production here in the Piedmont as well as to other locations worldwide at will."

The design of the new Levitex seals imposes very high requirements: The material composition must be exactly right, and the geometric form must strictly be adhered to. "That is why we have incorporated quality checks at several points in the production process," Scarano said. After each assembly step, laser sensors in the subsequent equipment precisely measure the geometry and position of the particular component. To some extent, that means the production process is self-monitoring. In a separate work step, the engineers also use a tool called an interferometer to check the condition of the ring surfaces. When the assembly is complete, a leakage test is carried out with air to ensure the component's reliable operation.

The numerous quality checks are necessary because the assembly process has many separate steps. "We settled on a decentralized approach with the maximum simplicity, in

SEVEN ARMS
Several robots are used on the assembly line to largely automate production.

MEASURING AND TESTING
A number of quality checks are built into the process to preclude errors in the many work steps.

which the individual production modules work independently of one another," Scarano said. "Each individual module is laid out so that it can execute its particular work step as effectively as possible. As a result, these technically demanding seals can be produced with a relatively simple architecture." But the production data are then consolidated centrally: After assembly, a laser engraves a serial number on each separate seal ring, under which individual product characteristics such as surface condition, geometry, weight and date of manufacture are recorded. "The possibility of tracing every single product is a special feature and was a main requirement for production planning," Scarano said.

OF INTEREST FOR ELECTRIC CARS

Modular assembly offers still other advantages by making it possible to integrate customer requests into the production process relatively easily. "For example, the sealing rings that we are now bringing to series readiness are equipped with an extra sensor, which passes an electric signal on to the engine control unit for positioning," Scarano said. "Thanks to our modular approach, we were able to effectively carry out this specification and set up an anti-static area, which it required, within the production line." For the layout of final assembly, the Pinerolo engineers learned from experiences with similar approaches used at other Freudenberg Sealing Technologies facilities, such as those of their colleagues at Langres, France, where crankshaft seals are also produced.

After series production is launched in the coming year, Levitex seals will be installed in the next engine generation of a European automaker, ensuring that its vehicles use less fuel and emit less CO_2. "With the new technology, we are realizing our vision of a friction-free seal," Scarano said. "We expect that we can quickly add other customers for Levitex seals." The potential savings due to reduced friction on the crankshaft are up to 1 gram per kilometer driven. That adds up quickly – and takes on even greater significance in light of demanding CO_2 goals in the future. Ideally, friction should only occur where it is really needed. ◎

LEVITEX, THE SEAL WITH THE CUSHION OF AIR

In every internal combustion engine, seals ensure that oil stays in the engine compartment. An important sealing point in this system is the transition from the engine to the transmission, where the crankshaft is closed off with a ring seal at the crankcase. This is exactly where the new Levitex seals are used. At their core, they consist of two metal rings, one of which is firmly connected to the crankcase and the other to the crankshaft. The surfaces of the rings have small indentations with a depth of only a few microns.

When the crankshaft rotates, the surrounding air is pressed into the indentations; the result is a cushion of air that separates the sealing surfaces from one another and enables a nearly friction-free rotation of the shaft – this saves fuel and reduces CO_2 emissions. At the same time, to reduce the crankcase's vibrations and guarantee a functional air cushion, the carrier housing for the static metal ring is equipped with a rubber spring. When the shaft is no longer rotating, the metal rings close, preventing the escape of oil from the engine compartment during the stoppage. So that this occurs completely reliably, the mechanical face seals are given an additional coating.

Until now, gas-filled ring seals were only used in large industrial equipment. It was only their design, patented by Freudenberg Sealing Technologies, and the associated production processes that made it possible to transfer the idea to vehicle engines, where very little space is available for mounting.

LIFTING AND FLOATING
As soon as the crankshaft rotates,
the Levitex seal builds up a cushion of air.

I, COBOT

Modern robotics has achieved a dynamics that seems to be advancing relentlessly. Robotic arms have not been restricted to welding, attaching screws and painting for a long time. Today they can even operate. Will humans soon be superfluous? Things could also turn out quite differently…

Massive. Heavy. Hard steel with loud motors. As coworkers, industrial robots are intimidating. With good reason: The more rigid and heavier a robot is built, the more exact and stable its movements. And in manufacturing, the work is a matter of millimeters. The weld point must be placed with the same pinpoint precision on the first car as on the second – all the way to the thousandth.

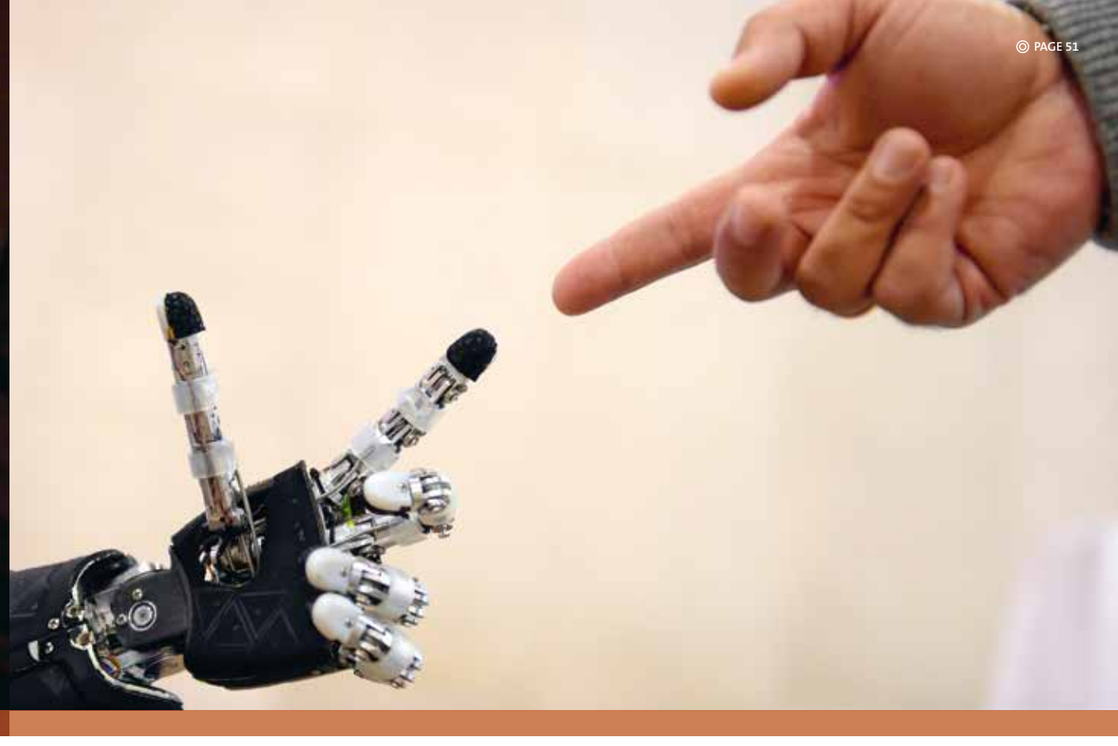
The robotic principle made its debut in manufacturing in 1805 when a loom that was programmable with a punch card first appeared. The machine succeeded the mechanical loom, and the robot followed it. Not only did they all work faster, but they never tire, they don't ask for vacations and they don't make careless mistakes. The model of humans as a labor source seemed on its way out.

ROBOTS TAKE CHARGE!

But more than 200 years after the first automatic loom, at least one thing is certain: The workers are still here. Even the dynamics of the robotic evolution could do them no harm – not the programmable painting machines that have been in use since the 1930s, not the robot arms first introduced in the 1960s, and not modern robots that can even play chess or the organ. But the debate is flaring up again. In newspapers, online media and social media timelines, the question of whether robots or artificial intelligence might do your job comes up regularly. The answer is (almost) always "yes!" "Industry 4.0," also known as "the fourth Industrial Revolution," really makes it sound as though robots – once and for all – are going to push workers onto the scrapheap of history.

It is undisputed that robots are still on the advance. It is still mainly the articulated-arm robots that we know from the shop floor and that seem rather antiquated compared to robot dogs with state-of-the-art designs. They represent the most-sold variety of all industrial robots purchased in 2015: 240,000 units worldwide – a sales record.

The fact that the limit is far from being reached likely has to do with the trend toward networking. The new age of manufacturing is banking on the idea that employees, machines and vehicles will be networking with one another and exchanging data. The newly delivered pallet sends a wireless message to the forklift, which begins moving without a



driver and brings it to its destination. Even today, only about 8 percent of all work in factories is automated – mostly tasks that are repetitive and not very complex to perform. But in ten years, one-quarter of all work could be handled with automation.

THE COBOT AS THE NEXT EVOLUTIONARY STAGE

And then there is a new generation of robots. It will focus on far more than the monotonous tasks of the unitary machines of past decades. The term "cobots," or collaborating robots, is already making the rounds. Together with their human colleagues, they can handle a multitude of highly complex and diverse work. Nearly every well-known robot manufacturer is now developing at least one model of this type. The cutthroat competition with robots that workers had perceived seems to have increasingly turned into conscious cooperation between the two.

In any case, employment figures suggest that robots have not made workers obsolete. In Germany's auto industry, considered one of the most automated sectors in the world, the number of employees rose an average of 2.5 percent between 2010 and 2016 – despite the fact that it added an average of 3 percent more robots annually during the same period. Why is that? Robots need someone to program, monitor and adjust them. Robots need people. At the same time, it is true that wherever growth results from the use of robots, more jobs – and especially more entirely new jobs – are created. Experts find that the amount of work is not reduced due to robots and computers. Its value even rises.

"MR. ROBOT, SWAB AND SHEARS PLEASE!"

In the operating room, for example: Here robots can do things that even experienced surgeons cannot successfully perform. They can make extremely small incisions with the greatest possible precision. Procedures with an accuracy down to one tenth of a millimeter (three-thousandth of an inch); incisions that would hardly be achievable even with extensive experience and absolute concentration. The massive articulated-arm robots of old have long evolved into highly sensitive, delicate creatures. But in the operating room, people emphasize that the "cobot" is becoming an assistant – and nothing more. Ultimately, far too many decisions have to be made during an operation, and that is – and will continue to be – the domain of human beings.

In reality, even monotonous production processes best handled by machines are being presented in differentiated ways. One prediction foresees the individualization of production. The customer will no longer be satisfied with mass-produced articles. He will value self-determination. Even today, whether a vehicle is a car or a forklift, it hardly leaves the factory anymore in the same form as the one before or after it. Individual preferences, customer-specific adjustments – robots, machines and networking can indeed provide support for all of this. But at some point, it always takes the human brain to execute the details. Even the giant mail order company Amazon does comparatively little of its work using conveyor belts or pallets. Here automation especially takes place at very specific points such as packaging. When it comes to collecting and picking very different products, the human hand is still the quickest and most efficient tool.

COBOT, MY FRIEND AND HELPER

Certainly, robots and automated machines can help at precisely this point. Where the worker previously had to drive the tugger train through the high rack storage area, climb in and out, stack boxes, and drive on, today the tugger train can follow the warehouse worker independently like a dutiful dog. Robotics and networking make this possible. Not least of all, demographic trends demand this. After all, who in their mid-60s are as physically robust as they were in their mid-30s? In the future, age will no longer be a reason not to transport heavy loads since robots will be providing the muscle power.

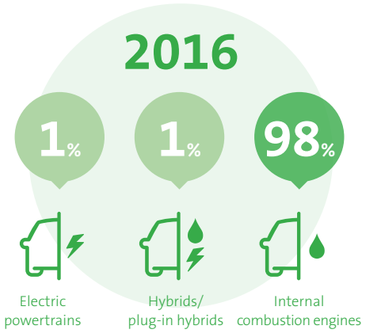
At the same time, employees have every reason to be more demanding and require mechanical help. Something that removes the dangerous and arduous aspects of a work step. Something that engages and even learns. That is exactly what the cobot promises. In doing so, it will be just as dependent on its human coworker as the reverse. The intimidating robotic coworker of former times could instead become Cobot, my friend and helper. ◎

DUAL STRATEGY

An affordable electric car with a decent range that can be quickly charged anywhere? What seemed impossible not long ago is expected to become a reality. But major production volumes are only likely to get rolling in 2050. That’s why automakers and suppliers are working on more efficient internal combustion engines at the same time.

It is mid-March, and the weather is bright and beautiful. For the attendees at the Stuttgart Symposium for Automotive and Engine Technology in Germany, it would be the perfect time to skip the next portion of the conference. But all the seats in König Karl Hall are taken as Ola Källenius ascends the stage. Named as the chief developer at Mercedes-Benz early this year, he is making his first public appearance in his new role. He plans to present his powertrain strategy for the next ten years to more than 700 engineers. “I am starting with the internal combustion engine, since it will dominate the market for many, many years,” Källenius said. Then he explains the billions in investments in a new generation of diesel and gasoline engines and raves about the “fabulous six-cylinder diesel” in the new S-Class. But after a dozen charts, the logo “EQ” is emblazoning the projection screen. “The time is now ripe to invest in electric mobility to a greater degree,” Källenius says. By 2025, the company will bring out ten purely electric models. The first, a compact SUV, will be introduced in early 2019. It will also bring out a large number of plug-in hybrids, whose electric range is supposed to increase to 50 kilometers (30 miles).

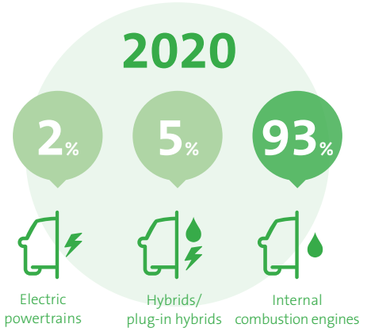
MARKET SHARES FOR CAR POWERTRAINS
(in the EU, USA and Canada)



The strategy of most automakers is best described as: Do one without neglecting the other. At one level, the electric car would be a loophole making it possible to meet the increasingly strict CO_2 regulations in large swaths of the world. Since carbon dioxide emissions resulting from the generation of electricity are not counted against automakers, a battery-powered car nominally runs emission-free. So every electric car sold clearly improves a manufacturer's fleet emissions score. On another level, it is still mostly an open question as to how quickly customers will actually accept electric cars and how sales will trend in the future. Most forecasts assume that the global market for cars will grow to 110 to 120 million new cars by 2030. But only one in ten will totally do without an internal combustion engine. At least one-third, however, will likely be driven electrically at least part of the time thanks to their hybrid powertrain.

A recent survey of German drivers by the testing organization Dekra shows that confidence in electric mobility is not very pronounced at this time. Only one in four can now imagine, at least theoretically, buying an electric car. A full 91 percent of those surveyed cited excessively high purchase prices as an obstacle. Nearly as many people criticize the shortage of charging stations and the cars' limited range. And 76 percent are troubled by the long charging times. Potential customers are thus citing the exact issues that the auto industry is tackling intensively.

MARKET SHARE FORECAST
FOR CAR POWERTRAINS
(in the EU, USA and Canada)

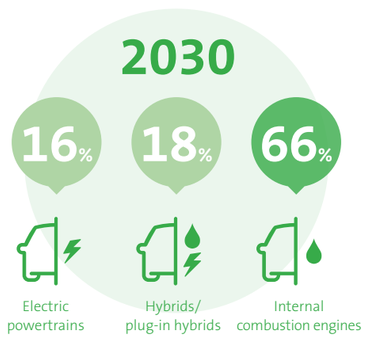


The higher purchase price can largely be traced to the battery. But doesn't it decline automatically to the extent that higher volumes are produced? A study last year by the engineering services provider FEV found that an electric car will even be more expensive than a vehicle with an internal combustion engine in 2025, even with volume production. If a range of 600 kilometers (370 miles) and a sustained powertrain output of 80 kW is presumed for a compact car, the pure production costs for the powertrain amount to 8,900 euros, with the battery accounting for 6,600 euros of that sum. The production of a comparable vehicle with a gasoline engine and dual clutch transmission would still be 3,200 euros cheaper despite the rising cost of exhaust treatment. And then there is the fact that the production costs account for less than half of the purchase price, just due to the huge development expenditures. Still, the gap between the internal combustion engine and the electric powertrain continues to shrink. Over the course of the next decade, many experts expect that electric powertrains will become cheaper than diesels, at least for small vehicles, since the exhaust treatment for diesels is particularly costly.

MORE CHARGING STATIONS

When drivers lament the deficient charging infrastructure, they are not talking about electric outlets at home, but the option of charging their cars when they are on the go. In fact, the number of publicly accessible charging stations is still limited. In mid-2016, according to the German Association of Energy and Water Industries (BDEW), there were exactly 6,517 charging locations available, based on the latest figures. That compares to about 14,000 filling stations for gasoline and diesel, which certainly offer more than one pump per site. The German federal government has launched a 300-million-euro program to accelerate the expansion of the public infrastructure. It envisions the construction of 10,000 additional regular charging stations for 200 million euros, and another 100 million euros will flow into a network of 5,000 fast-charging stations. The latter work with direct current and generally with an output of about 50 kW – more than ten times the performance of a domestic three-phase alternating current outlet. Much higher charging capacities have increasingly come up in industry discussions; up to 350 kW has been mentioned. That would mean that an e-Golf with an existing battery could be charged up with sufficient electric current for a 300-kilometers trip (190 miles) in ten minutes – unfortunately only in theory, since a number of hurdles still exist in practice. For example, the energy-absorbing capacity of a lithium ion battery shrinks as the amount of current already in the battery increases. In addition, the battery heats up during fast charging and the speed has to be throttled back. The challenge facing the electric infrastructure is even more serious: One freeway filling station, with just ten such extremely fast-charging stations operating simultaneously, requires a power rating of 3.5 megawatts – which is equivalent to a small cogeneration plant or one wind turbine operating at full load.

MARKET SHARE FORECAST
FOR CAR POWERTRAINS
(in the EU, USA and Canada)



IMPROVED BATTERIES

How far an electric car travels depends on how much electricity it can carry and how efficiently it converts electric power into forward motion. The energy-related storage density of the lithium ion batteries in use today has continually improved in recent years. But the current technology seems to exhaust its potential at 150 to 180 watt-hours per kilo (on the cell level). The National Electric Mobility Platform only expects a significant leap – meaning a doubling of energy density – with new technologies that are either based on solid-state electrolytes or a switch to lithium-sulfur technology. In 2025 at the earliest, according to the official forecast, a completely new generation of batteries could find its way into cars. It will still be important to deal with these costly energy storage devices efficiently. Thermal management is a major control lever for this development. The reason is that today's lithium ion batteries reach their maximum capacity at temperatures between 20 and 40°C (68 and 104°F). The range also falls significantly when it is hot or cold outside because a portion of the electric current flows into the air-conditioning or heating unit. A sophisticated thermal management system can moderate this effect.

The huge sums that the auto industry is now investing in the continued development of the electric car are expected to bear fruit soon. Claus Möhlenkamp, CEO of Freudenberg Sealing Technologies, said he is convinced that "the known obstacles to battery-powered vehicles, such as energy density, range and charging speed, along with the ongoing excessive costs, can be overcome with a systematic approach to research and development." But Möhlenkamp is not only banking on these efforts. "We must not lose sight of conventional powertrains. They will still be with us for quite a while. New ideas are needed for them as well." But if the internal combustion engine is to be completely replaced one day, it is essential to get hydrogen-powered fuel cells in shape for series production. "When it comes to CO_2-neutral, long-distance transportation, the fuel cell is presumably the only option." But the electric current produced in the fuel cell is also converted into forward motion with an electric powertrain and presumably stored temporarily in a battery in some cases. In this way, the fuel cell drive system benefits from advances in the development of the electric car. These advances are significant, probably as significant as those of the internal combustion engine in the era of Nicolaus August Otto and Rudolf Diesel. ©

Worth Knowing

A NEW GENERATION

Reduced fuel consumption, lower emissions and a longer operating life for powertrain systems: Automakers aren't the only companies facing these challenges – producers of mobile work machines and heavy equipment are addressing them as well. Freudenberg is supporting them with innovative products such as the transmission seal Levitas and the thrust washer Levitorq.

Seals are responsible for nearly one-quarter of the total mechanical energy losses in today's automatic transmissions. Manufacturers are going all out to reduce friction in transmissions to keep these losses as low as possible. In early March, Freudenberg Sealing Technologies presented a new generation of low-friction sealing products: the transmission seal Levitas and the thrust washer Levitorq.

"Manufacturers of mobile work machinery and heavy equipment face the same challenges as automakers: more stringent environmental regulations, rising fuel prices and extended maintenance intervals," said Joel Johnson, Vice President of the Mobile Machinery business field. "Our company has fully focused its activities in material development and product design on a solution to these problems."

The Levitas seal rings are suited for all types of automated transmissions. During operation, the special design of the seal leads to the formation of a hydrodynamic oil film between the seal and the opposite surface, where the seal floats in an especially low-friction state. This reduces the frictional torque in an automatic transmission by up to 70 percent compared to a conventional seal – since only fluid friction results.

Freudenberg's Levitorq thrust washers also employ a hydrodynamic oil film. They are conceived in such a way that a bearing can run on – or a force can act on – their bearing face. Thrust washers have traditionally been made of metal. Freudenberg has developed thermoplastic or duroplastic options, which are replacing the heavy metallic thrust washers. This reduces friction as well as the weight of the components, lowering the customer's costs in the process.

Both products are components of the Low Emission Sealing Solutions (LESS) initiative, in which Freudenberg Sealing Technologies bundles product innovations that reduce frictional losses, installation space, weight, fuel consumption and emissions. ◎

SMOOTH AS SILK

The overall efficiency of a vehicle powertrain has largely been dependent on the transmission. That's why all transmission manufacturers are working to minimize frictional losses. One new technology for transmission seals from Freudenberg Sealing Technologies not only reduces friction – it significantly cuts CO_2 emissions as well.

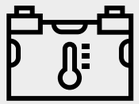
Levitas seal rings are suited for installation in all automated transmissions. The seal's special design promotes the formation of a hydrodynamic oil film between the seal and the opposite surface during operation. This reduces friction to the point that the vehicle's CO_2 emissions are reduced by 0.8 grams per kilometer. If a million new vehicles were equipped with Levitas seals, the accumulated emissions would drop by 192,000 tons over their entire operating life. "The solution is also of interest to European car and transmission manufacturers due to increasingly stringent CO_2 limit values," said Dr. Eberhard Bock, Director, Strategic Product Development at Freudenberg Sealing Technologies.

About one-quarter of the overall mechanical energy in an automatic transmission is lost through its seals. Seals maintain the oil pressure in the transmission at the target level, which enables excellent shifting. It is important to keep leakage as low as possible, meaning that very little oil flows past the seal. "Today the most important goal in the development of new seals is to make low leakage rates and minimal friction possible at the same time," said Hikaru Tadano of Freudenberg Sealing Technologies' Advanced Development department. Until now, this conflict was resolved with a reduced contact surface that diminished friction. "However, further reductions in friction using even smaller contact surfaces are no longer possible", Tadano said.

With Levitas, Freudenberg Sealing Technologies is pursuing an entirely new approach: During operation, the seal floats on a hydrodynamic oil film that it produces itself. Since there is no longer physical contact between the shaft and the seal ring, only fluid friction remains. This reduces frictional torque by up to 70 percent. The Levitex engine seals just introduced by Freudenberg Sealing Technologies operate on a similar principle, although ambient air is used as the "lubricant" instead of oil. In this case, the frictional torque is nearly reduced to zero. ◎

NO FEARS OF HIGH HEAT

Better thermal management and increased safety: With the new generation of electric vehicles, the demands on their batteries are increasing. Freudenberg Sealing Technologies anticipated this stage years ago.



Lithium ion batteries are in flux. With the next generation of electric cars already arriving this year, the demands on batteries are changing as well: more energy, faster charging times. “From now on, batteries will be subject to the greatest stress during charging – no longer driving and accelerating anymore,” said Dr. Peter Kritzer, Innovation Leader at Freudenberg Sealing Technologies. But that also means safety requirements are greatly increasing. “If I have double the energy in the same space, the chemical reaction resulting from it is not just twice as fast – it is faster many times over,” Kritzer said. That brings issues like thermal management and safety more fully into focus. “Years ago, we developed a number of concepts relating to how the safety, in particular, of such systems can be improved,” he said.

Kritzer has been fielding more queries on these issues recently. This also has to do with the fact that FST is offering automakers the chance to jointly develop concepts and then team up to implement them in series production. “Three years ago, the appeal of these concepts was rather limited because the first generation of lithium ion batteries was quite tame,” he said.

FASTER CHARGING AT HIGHER DENSITY

It is clear that electric cars are taking the next step. While most vehicles have only been able to drive about 150 kilometers (95 miles) on a single battery charge until now, the next generation will more than double that distance. But their components so far have been geared to shorter ranges. In the future, either the energy density in the individual cells will have to be increased or the cells in the battery system will have to be packed more closely together.

The second generation of electric cars has been conceived for an electric powertrain – which means more space is available for the battery system. Since the batteries are supposed to recover 80 percent of their capacity in 15 to 30 minutes, increased energy flows are required. But these energy flows lead to greater battery heating during charging. “If the components of the prior battery systems are just carried over to the new battery generations, safety issues can arise,” Kritzer said.

“In principle, for example, a housing seal for battery systems seems comparatively simple,” he said. But special attention must be paid to the design due to the safety requirements: Just penetration by water could cause severe damage. The pressure balance of the battery housing is another issue. In this area, automakers have worked with elements of microporous film. They were especially watertight but hardly permeable to air at all. The battery in turn needs an exchange of air and elements with large surface areas, which enlarges the system. One of the developments is a special pressure equalization element. It contains a nonwoven that is watertight yet has much greater permeability to air than a microporous film. And even more, it functions as a degassing element in emergencies. “We get by with just one-fifth or even one-tenth of the space while offering the added value of pressure degassing and overpressure functions,” Kritzer said.

PARTNER FOR COOLING AND SAFETY

Other examples of the company’s developments include a specially designed piston in which a battery can, so to speak, breathe. In this way, the battery system can be completely sealed off from the environment. That translates to protection from moisture as well as a simultaneous opportunity to charge the system with a protective gas atmosphere.

“Our general approach is to think a step ahead with our customers,” Kritzer said. “We see ourselves as a partner in cooling and safety.” Freudenberg Sealing Technologies has formed a special unit to meet the new requirements of electric mobility. The vehicles following the next generation will usher in the breakthrough for electric vehicles. “And when electric cars are present in the market in large numbers, the safety requirements will increase once again,” he said. ◎

IN THE FLOW OF FORCES

At Freudenberg Sealing Technologies' plant in Schwalmstadt, everything revolves around hydraulics and pneumatics – the power of fluids to move a cylinder. In laboratories, material experts mix new combinations of substances, and product developers use them to create new fluid seals. Their shared goal: Innovative seals that deliver the best possible performance even under high pressure.

TOUGH AS NAILS
Hydraulic seals must withstand pressures of up to 400 bar.

Our safety shoes with the steel toes are laced up tightly, and we are wearing safety glasses as we enter the test bay at Freudenberg Sealing Technologies' plant in Schwalmstadt, (Germany). In a corner, surrounded by more than a dozen fairly small and medium-sized test stands, a larger version for rod seals is emitting high-volume, pulsating noises as it works. Gonzalo Barillas walks purposefully over to a compact, blue installation, which looks like a cabinet with drawers. "That is our new seal test stand for hydraulic rods," said Barillas, who is head of advanced development. At temperatures of up to 100°C and hydraulic pressures up to 400 bar, products that seal rods against cylinders in hydraulic cylinders are shunted back and forth at least 50,000 times per test cycle.

"With our test stands, we record and evaluate the functional reliability and behavior of individual fluid seals and entire sealing systems," Barillas said. "Our new test stand makes this especially efficient because we carry out the actual movement with an electrical drive, and the hydraulic assembly only has to build up the system pressure – and thus can be designed considerably smaller." This also leads to much less noise. And because the electric drive can execute the stroke movements much more dynamically, the throughput time for a durability test has been cut by more than half.

At the plant in Schwalmstadt, which is devoted to Freudenberg Sealing Technologies' industrial segment, everything revolves around hydraulics and

pneumatics, meaning the fluid forces that move a cylinder. The term “fluids” refers to hydraulic fluids like water as well as air and other gases for pneumatic applications. A number of factors are of crucial importance for the performance of hydraulic and pneumatic cylinders: positioning, design and the material characteristics of the ring seals on the surface of the piston rods. This is precisely where many parameters intersect and must be brought into harmony, including the basically opposing parameters of leak tightness, minimal friction and a long operating life.

EXACTLY CALIBRATED ELEMENTS

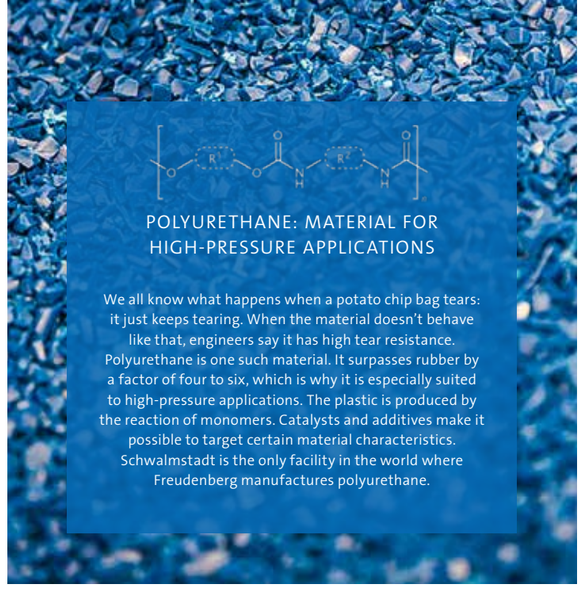
That’s why the Schwalmstadt engineers develop sealing systems consisting of individual elements precisely calibrated to one another. For example, piston seals transmit hydraulic forces of up to 700 bar. Rod seals and static seals in the cylinder cover prevent leaks. Guide elements made of hard tissue promote the absorption of side forces as well as the optimal positioning of the piston rods in the cylinder, and so-called wipers protect the system against contamination from the outside. Among other uses, the hydraulic assemblies do their jobs in wheel loaders, excavators and garbage vehicles, which often expose them to high levels of mud and dirt. Pneumatic cylinders are used in automation units – for example, for the automated transport of small parts in manufacturing processes – and in door-closing mechanisms on buses and trains. “You can basically say that hydraulic assemblies are used wherever a great deal of force is required,” Barillas said. “By contrast, pneumatics always plays a role when a great many individual movements at very high speeds are required, but at comparatively moderate power.”

The multifaceted nature of fluid power applications leads Freudenberg Sealing Technologies engineers to constantly improve their hydraulic and pneumatic sealing systems and to keep researching new sealing solutions. “The work on a new development starts out with either a specific desire of a customer, perhaps due to greater temperature demands on the material, or new circumstances relating to raw materials, perhaps due to changes in availability or legal requirements,” said Dr. Jürgen Hieber, who is in charge of material development at Schwalmstadt. Working with product development and applications engineers, the project team develops a specifications book, which defines the key material characteristics such as resistance to high and low temperatures, pressures, tearing and media, along with frictional values and tensile strength. “On this basis, we then consider which raw material combinations are basically conceivable for these requirements.” Due to its very good suitability for high-pressure applications, in part because of its excellent tear resistance, Hieber mostly turns to polyurethane – a plastic that Freudenberg Sealing Technologies exclusively produces at Schwalmstadt, although elastomers and other materials are also used in seals.

In the lab, the raw materials for polyurethane production, known as monomers, are mixed in a reactor and synthesized into polymers with the application of certain temperatures and various catalysts. The material developers then produce a granulate out of the resulting hardened plates. To test new compounds, they mold the granulate in injection molding machines, producing various test specimens in disc or bar form. They then investigate, for example, when the new material become soft or melts and how it behaves at cold temperatures. Experts also check how resistant the new material is to oils and media. When it ultimately fulfills the requirements from the specification book, the material developers then make it available in one or more versions to their colleagues in product development – who design the seal with simulations and then build various prototypes.

These prototypes then land on the numerous test stands in the test bay – for example, the new seal test stand for hydraulic rods. “It is generally very important for new products to be tested comprehensively in the development phase,” Barillas said. “After the market launch, we carry out tests simultaneously with series production to ensure the consistent quality of our seals.” Occasionally, the polyurethane know-how is even in demand for special products that have nothing to do with hydraulics and pneumatics. For example, the Schwalmstadt facility produces wear-resistant plastic discs for high-speed rotating textile machines and long-lasting polyurethane molded parts for hydrants. ◎

IN EXCAVATORS AND WASTE VEHICLES
Hydraulic seals are rarely employed in clinically clean environments.



POLYURETHANE: MATERIAL FOR HIGH-PRESSURE APPLICATIONS

We all know what happens when a potato chip bag tears: it just keeps tearing. When the material doesn’t behave like that, engineers say it has high tear resistance. Polyurethane is one such material. It surpasses rubber by a factor of four to six, which is why it is especially suited to high-pressure applications. The plastic is produced by the reaction of monomers. Catalysts and additives make it possible to target certain material characteristics. Schwalmstadt is the only facility in the world where Freudenberg manufactures polyurethane.

DILIGENT WORK FOR THE REVOLUTION

Self-driven electric cars could revolutionize urban transportation in ten years. But the implementation of big ideas demands solid engineering work. IAV, an engineering partner in which Freudenberg holds a 10 percent stake, is working with 7,000 sharp minds on technologies for autonomous, emission-free and networked vehicles.

ALWAYS ROOM FOR IMPROVEMENT
Vehicle batteries on a special
IAV test stand.

The car has to adapt to the city – not the other way around. Shanghai was still a city of bicycles, and Uber founder Travis Kalanick was still in primary school. An insight was taking shape in Hermann Appel's mind – that the future required new mobility concepts. In 1983, Appel, whose main job was working as a professor of vehicle technology at the Technical University of Berlin, founded IAV, an engineering company focusing on the automobile and transportation, with a few colleagues and support from Volkswagen. One of his most important concerns: developing environmentally friendly and safe vehicle concepts for urban areas.

Thirty-four years later: IAV still has its headquarters on the Spree, just a few minutes' walk from the university. But more than two-thirds of its employees, who now number 7,000, work at other locations. They reside in 32 development facilities outside the gates of large auto manufacturers, in Gifhorn near Wolfsburg as well as in Stuttgart and Shanghai. They develop vehicle powertrains, electronic assistance systems and even complete cars. Their exact work has to stay secret. In the end, the product bears the manufacturer's logo, and IAV is committed to confidentiality.

"Our aspiration is still to shape mobility," said Kurt Blumenröder, the company's longtime CEO. "Digitization can make an important contribution to this." In doing so, IAV can serve as a bridge builder, he said. The IT sector is indeed becoming an indispensable partner to the auto industry. "But it often does not understand the processes of automobile development," Blumenröder said. IAV responds to this state of affairs by actively seeking partnerships with companies such as HP or Microsoft. "That is how we develop the know-how – for example, in the field of artificial intelligence – that will be needed to build automated, emission-free and networked cars." One of IAV's key fields is powertrain development. The advance of electrification is leading to a complexity that is increasing faster than the number of employees at the manufacturers. "To our customers, it is not so much a matter of capacity as it is finding employees who have wide-ranging experience in the development of electric and hybrid vehicles," Blumenröder said. He is referring to people like Wolfgang Reimann, who is in charge of the development of electric and hybrid powertrains. On the electric scene, Reimann is considered to be one of the original old hands. He collaborated on a short production run of 120 urban electric vehicles based on the Volkswagen Golf II. With great difficulty, they managed a speed of 100 km/h (62 mph) and a range of just 50 to 70 kilometers (30 to 45 miles) per battery charge.

Reimann doesn't have the time to think about the past. By 2020, in time for the tightening of the EU's CO_2 provisions, numerous manufacturers are bringing out new electric cars with significantly improved performance figures. To be sure, their basic outlines have been developed – in part with the help of IAV. "We did the actual pioneering work four to five years ago." Now the companies have to get the cars in shape for comparisons with conventional vehicles. In the process, a multitude of troublesome details are emerging that must be worked out before series production is launched. In some cases, a component in the battery system has not been sufficiently developed. In others, the range falls more quickly than expected in cold weather. No matter where the problem occurs, Reimann and a troop of about 600 IAV development engineers are ready to help. When necessary, he will drive out to see a customer even on short notice on a Friday afternoon to examine test results on site.

But supporting the customer during series production development is just one side of Reimann's work. The other side extends further into the future. That's because electric mobility could get an additional push starting in 2025. "For one thing, the legal requirements are being tightened further," Reimann said. "For another, it is likely that new vehicle concepts and alternative battery technologies will be ready for the market." For example, in ten years autonomously piloted "people movers" could be part of the street scenes in major cities. Powertrains, batteries and chassis will be positioned completely beneath the passenger compartment floor, and the superstructure above it could be freely designed. Passengers could conceivably sit with their backs to the driving direction or even stand. "This poses completely new development challenges," Reimann said. "After all, vehicles of this type should also offer perfect safety." This includes sensitive, proactive regulation of the powertrain.

IAV CEO Blumenröder regularly discusses what such trends mean for suppliers with the top management of Freudenberg Sealing Technologies, whose holding company Freudenberg SE has a 10 percent stake in IAV. But there are also regular exchanges among the experts of the two companies. They involve how seal rings for fast-rotating electric motors must be procured or what electrically conductive plastics can do. They are ostensibly small things that nonetheless are determining whether the dream of a perfect city car becomes a reality. ◎

CREATING FOUNDATIONS
With its own research, IAV is improving
the technology of electric vehicles.

Worth Knowing

NEW ASSEMBLY PROCESS FOR DIAPHRAGM ACCUMULATORS

Until now, the production of diaphragm accumulators has been very costly due to a multitude of production steps and components. That's why Freudenberg Sealing Technologies has developed a new, innovative electromagnetic pulse joining process to produce diaphragm accumulators. It has already received multiple awards for this development.

Diaphragm accumulators have traditionally consisted of a steel housing with a gas and a liquid portion separated by a diaphragm. If the pressure rises in the oil circuit, the accumulator takes up the liquid. In the process, the gas in the other portion of the hydraulic accumulator is compressed. If the pressure in the hydraulic system drops again, the gas expands and forces the stored liquid back into the oil circuit. In the auto industry, proven applications include energy storage in double clutch and automated transmissions, pulsation damping and the hydraulic systems for chassis damping. Besides the general storage of hydraulic energy, applications in other industrial sectors lead to increased cycle times and shortened lifting times in processes. But especially in standard applications, the multitude of production steps and components results in added production costs.

As a result, Freudenberg Sealing Technologies has developed a new concept for the production of diaphragm accumulators. The operation requires fewer process steps and components, which shortens assembly times. The nitrogen filling on the gas side and the joining of the two aluminum housing halves take place in the same step, the latter with the use of strong magnetic fields. This newly developed process offers a high degree of stability and component cleanliness. Thanks to this innovative approach and the use of aluminum as a lightweight material, new opportunities for diaphragm accumulators are emerging, for example, in hydropneumatic chassis applications.

Freudenberg Sealing Technologies has received the Rhineland-Palatinate Innovation Award, among other honors, for its new electromagnetic pulse joining process. The company was given the award in the "Special Award Industry" category. The Rhineland-Palatinate Innovation Award is one of the oldest innovation-related honors in Germany and is bestowed jointly by the Ministry of Economy, Transport, Agriculture and Viticulture and by the working group of the chambers for industry, trade and crafts. ◎

EFFICIENT SOLUTIONS

Whether hydraulic, pneumatic or fluid applications, Freudenberg Sealing Technologies offers numerous optimized solutions for hydraulic accumulators. FST thus makes a contribution to functional reliability and long operating lives. Advances in fuel efficiency and emission reductions can be achieved with this approach.

Freudenberg Sealing Technologies offers a unique selection of piston, diaphragm and bladder accumulators in different volumes for stationary and mobile applications. These hydraulic accumulators are based on the company's own development of elastomer materials and sealing solutions. That explains why they are not just optimized for the customer – they are designed to meet special customized requirements as well. For example, they have a range of different oil and gas connections. These hydraulic accumulators also withstand high operating pressures of up to 1,500 bar and high dynamic loads. At the same time, they exhibit bursting-pressure strength and can be used in a broad range of temperatures.

"Our hydraulic accumulators can be individually changed, based on the customer's desires. Factors such as size, fluid volume, operating pressure and resistance to corrosion can be adjusted to meet country-specific certification requirements," said Kurt Ziminski, Head of the Freudenberg Sealing Technologies Accumulators Division. "Thanks to our technical expertise in material development and product design, we can offer our customers a wide variety of options, both in industrial applications and for unique diaphragm, seal or housing options. ◎

OUTSTANDING SUPPLIER

Freudenberg-NOK Sealing can take satisfaction in winning the coveted Achieving Excellence (AE) Supplier Performance Partner Rating from John Deere Power Systems in North America. The award especially highlighted Freudenberg-NOK's outstanding performance in quality, on-time delivery and technical support.

In North America, Freudenberg-NOK supplies John Deere Power Systems with high-quality components. They include radial shaft seal rings, valve stem seals, plug connections and sealing packages for pistons and piston rods. The two companies also work closely in product development and in technical engineering programs such as value analysis and value engineering.

Suppliers participating in John Deere Power Systems' Achieving Excellence program, which was launched in 1991, are critically examined annually based on a series of key figures relating to quality, cost management, on-time delivery and customer service, among other criteria. The Freudenberg-NOK plants in the U.S. and Mexico that underwent the evaluation received nearly the maximum point totals in many categories.

"John Deere Power Systems' presentation of the Partner Rating is the result of a very productive relationship between our two companies over nearly two decades," said Joel Johnson, Freudenberg-NOK's Vice President Mobile Machinery. "We are very proud of this top supplier rating and happy that our years of service have contributed to the growth and success of John Deere Power Systems." ◎

SWISS PRECISION

Wearable insulin pumps can appreciably improve the quality of life of diabetes sufferers. The Lube&Seal concept from Freudenberg Sealing Technologies has made a crucial contribution to a new pump from the Swiss medical technology specialist Ypsomed.

Two cans of cola and three spoonsful of sugar. That's how Bobby Clarke prepared for every game. The ice hockey player is a legend in the United States and is now nearing 70 years old. Even in his youth, he suffered from Type I diabetes, an autoimmune disease that ultimately causes the pancreas to cease producing insulin. Unlike Type II diabetics, the ailment cannot be influenced by lifestyle changes. According to the International Diabetes Federation, more than a half million children worldwide under the age of 14 suffer from this blood sugar-related illness. If insulin is not continually introduced into the patient, he goes into a coma due to excessive blood sugar levels. On the other hand, the effect of the insulin can become too strong during unplanned physical activity, threatening to produce a state known as low blood sugar.

The remedy is insulin therapy, which consists of the constant control of the blood sugar level and the delivery of insulin based on need – that is, taking meals and athletic activities into consideration. To limit the individual's quality of life as little as possible, the first wearable, albeit cumbersome, insulin pumps were developed during the 1980s. Today's pumps can be worn right on the body. The Swiss medical technology specialist Ypsomed is introducing the "mylife™ YpsoPump®," an extremely small pump. The black device weighs 83 grams (3 ounces), is just 16 millimeters (0.6 inch) thick, and has won several design awards. "It was not easy to house the entire technology in such a narrow space," said René Mathys, who shares the responsibility for developing infusion systems at Ypsomed. That's because the battery and the cartridge with the vital insulin must be housed there as well.

MINIMAL FRICTION AND SPECIAL GREASE

The insulin dosing must occur with a precision down to 1 millionth of a liter (0.1 units of insulin), so the patient's metabolism stays in equilibrium. A precisely functioning electric motor is integrated into the drive developed by the company. Following a precisely defined path, the drive presses a punch into the cartridge where the supply of insulin is held. Since the blood sugar level and the insulin dose are not continually aligned, the forces in the drive are monitored to estimate whether the administered dose matches the prescribed value. The small infeed seal, which seals the driveshaft at the transition to the cartridge space, initially created headaches for Ypsomed's developers. Tests on the seal from another manufacturer showed that it produced too much friction, hindering the precise control of the supply. Ypsomed sought help from Freudenberg Sealing Technologies Switzerland. Patrick Kinsch, Product Developer at Freudenberg facility in Schwalmstadt (Germany), ultimately found a solution. He turned to a grooved rod seal whose surface roughness was significantly reduced by a nano-technology process. The friction was reduced to a torque of just four thousandths of a newton meter. "This is a sensational value for a seal, especially when its counterpart, the threaded sleeve, is rotating at a maximum of 100 rpm and a high degree of leak tightness has to be guaranteed – but it was still too much for this application," Kinsch said. That's why he brought lubrication experts on board, and they quickly found a solution: A grease based on perfluorinated polyether oils, dosed in a quantity of less than a gram, made it possible to cut the torque produced by friction in half. PFPE lubricants are far superior to conventional greases – they are even used in space flight. The development work was concluded in a year. "Without the combination of an innovative seal solution and the right lubricant, we would not have reached our goal," Mathys said with satisfaction.

IN USE FOR 35,000 HOURS

Reduced friction also means less susceptibility to wear. "For example, an insulin pump runs without interruption for more than 35,000 hours," Mathys said. "Due to this long lifespan, it is extremely important for each individual component to make it through this period without wear. As a result, Ypsomed is relying exclusively on precision parts. The core components of the drive come almost exclusively from Germany and Switzerland and were specially developed for insulin pumps. The drive and the pump are assembled at a high-tech facility in Burgdorf (Switzerland), which brings a Swiss clock factory to mind. "This is typical of the 'Swiss medical valley,'" said Peter Rohrer, Sales Engineer, Freudenberg Sealing Technologies Switzerland. He has coordinated the development of this sealing solution for Ypsomed since the first contact and assembled experts from various disciplines to work on it.

As important as the drive is to the operation of a wearable insulin pump, ease of use also plays a role in determining whether patients and medical staff accept the product. "Very early on, we decided to make it possible to handle the entire operation with a touch-sensitive display," Mathys said.

All the functions can be called up using graphic symbols – just like a smartphone. The patient can also transfer the data to his computer. The device's software permits the precise calibration of the preset insulin dose with the user's daily routine and eating habits – and allows the physician handling the therapy to steadily improve it. For safety reasons, the dosing can only be changed with the device itself.

The "mylifeTM YpsoPump®" has been used by patients in the Netherlands, United Kingdom and Germany since the fall of 2016. Other markets are expected to follow shortly. Ypsomed has deliberately decided on a slow production ramp-up. Careful market introductions are a component of Swiss precision as well. ◎

FEEDBACK & CONTACT

CURRENT, WIDE-RANGING INFORMATION

Would you like to know more about Freudenberg Sealing Technologies, our products, solutions and services? Stop by **www.fst.com** and discover our comprehensive portfolio. On our Internet site, you can download all editions of our customer magazine as a PDF or subscribe to the magazine at no charge.

If you would like to stop the shipment of "Essential" under the right of objection in the German data privacy law § 28 IV Clause 1 BDSG, simply send an email indicating your address to: **essential@fst.com**

WE LOOK FORWARD TO A DIALOG WITH YOU!

FREUDENBERG SEALING TECHNOLOGIES GMBH & CO. KG

ISOLDE GRABENAUER
+49 6201 80-7467
isolde.grabenauer@fst.com

MICHAEL SCHEUER
+49 6201 80-3631
michael.scheuer@fst.com

COMPANY INFORMATION

PUBLISHER
FREUDENBERG SEALING TECHNOLOGIES GMBH & CO. KG
Corporate Communications
Höhnerweg 2–4, D-69469 Weinheim

CONTENT RESPONSIBILITY
Michael Scheuer (V.i.S.d.P.)

EDITOR
Isolde Grabenauer

EDITORIAL
Profilwerkstatt GmbH,
Redaktionsbüro delta eta

DESIGN & CONCEPTION
Profilwerkstatt GmbH

PRINTING
ABT Print und Medien GmbH
Bruchsaler Straße 5
D-69469 Weinheim

PICTURE CREDITS/COPYRIGHT

p 3	Yuri Arcurs / iStockphoto.com	pp 26–27	INFOGRAPHICS GROUP GmbH	p 50	Bloomberg / gettyimages.com
pp 4–5	Akademischer Motorsportverein Zürich, Technische Hochschule Zürich und Hochschule Luzern	p 28	f11photo / shutterstock.com	p 51	Gerard Julien / gettyimages.com
		p 30	Andrey Bayda / shutterstock.com	p 52	Nancy Honey / gettyimages.com
pp 6–7	ilolab / shutterstock.com	p 31	Rik85 / shutterstock.com	pp 56–57	spreephoto.de
pp 8–9	cyano66 / iStockphoto.com	p 31	vaalaa / shutterstock.com	p 57	Eisenhans / Fotolia.com
pp 10–11	NASA	pp 32–33	INFOGRAPHICS GROUP GmbH	p 58	petovarga / Fotolia.com
	Olexandr / Adobe Stock	p 34	FST / picture alliance / Manuel Romano	pp 64-65	IAV
pp 12	MarkSwallow / gettyimages.com	p 36	FST / picture alliance / Manuel Romano	p 66	IAV
pp 13	Joe McNally / gettyimages.com	p 39	FST / picture alliance / Manuel Romano	p 67	IAV
pp 13	AYakovlev / iStockphoto.com	pp 40–41	Atlas Copco	pp 68–69	Rike / gettyimages.com
p 14	Visage / gettyimages.com	p. 42	Atlas Copco	p 70	Ypsomed AG
p 15	republica / gettyimages.com	p 43	Atlas Copco	p 70–71	SCIEPRO / gettyimages.com
p 22	Caterpillar	p 44	FST / picture alliance / Dinno Kovic		
p 23	Oak Ridge National Laboratory, US Dept of Energy	p 45	FST / picture alliance / Dinno Kovic		
		p 46	FST / picture alliance / Dinno Kovic		
p 24	Rudy Balasko / shutterstock.com	p 47	FST / picture alliance / Dinno Kovic		
		p 48	Bloomberg / gettyimages.com		

11 GB 007 3.5 10/16 osk/abc

How do we advance e-mobility? With over 1,000 experts in 60 countries, we are giving our customers from the automotive industry new impetus. Innovative power, quality and internationality make us a valuable technology and development partner who thinks holistically. Beyond the pure product application, we are striving for integrated solutions and systems that provide a future for sustainable mobility. What are your challenges for us? E-xperience more at **e-mobility.fst.com**

FREUDENBERG
SEALING TECHNOLOGIES

FREUDENBERG
INNOVATING TOGETHER

FREUDENBERG
SEALING TECHNOLOGIES

FREUDENBERG
INNOVATING TOGETHER