SULZER

Sulzer Technical Review

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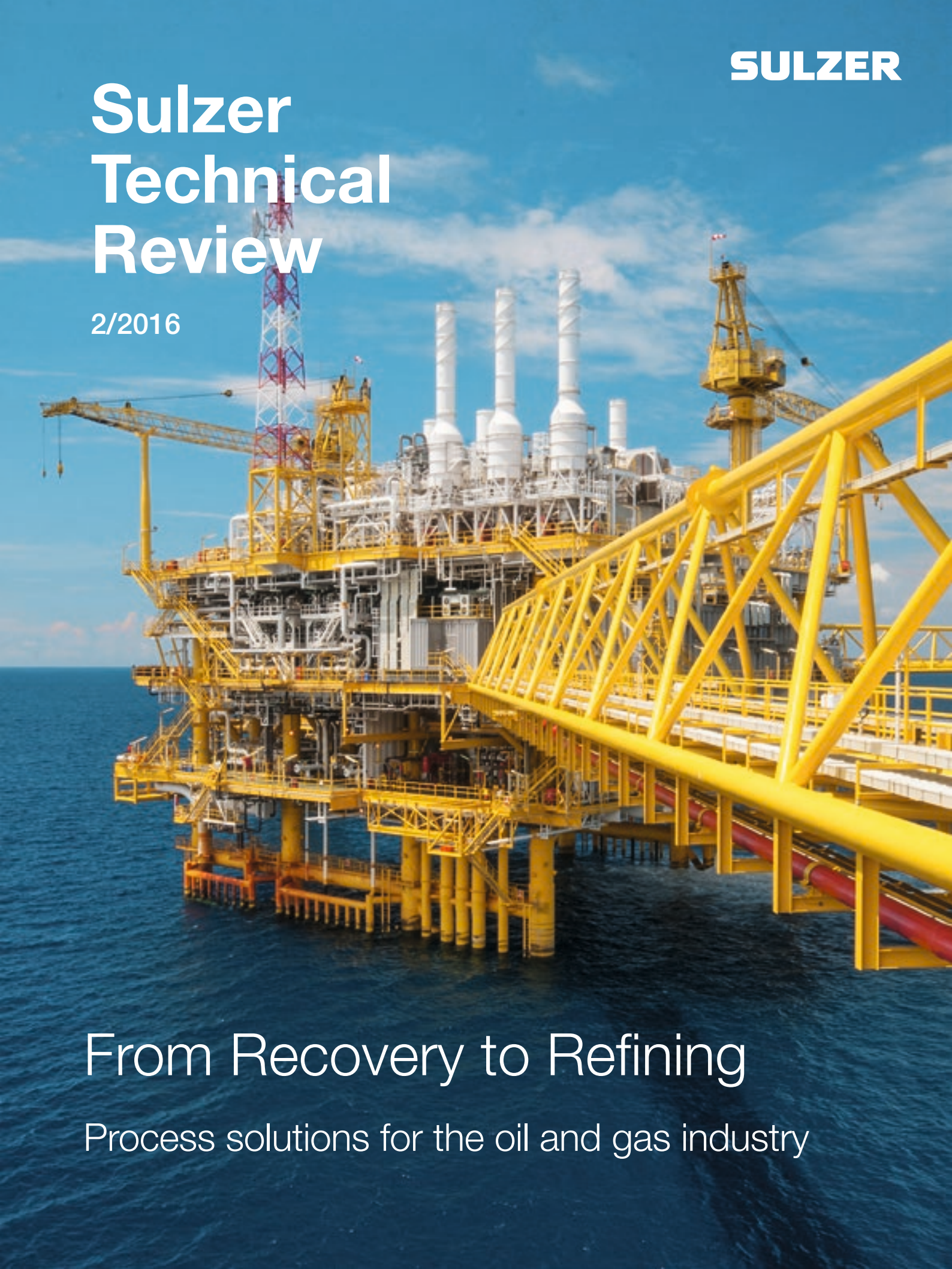


From Recovery to Refining

Process solutions for the oil and gas industry

"We provide innovative and cost-saving solutions."

Dear Technology Fans, Customers, and Partners,

The challenging market environment is placing the oil and gas industry under severe cost pressure. This issue of the *Sulzer Technical Review* bears the title "From Recovery to Refining." Here, we are portraying our innovative solutions in this market and how they lead to process optimizations and cost savings for our customers.

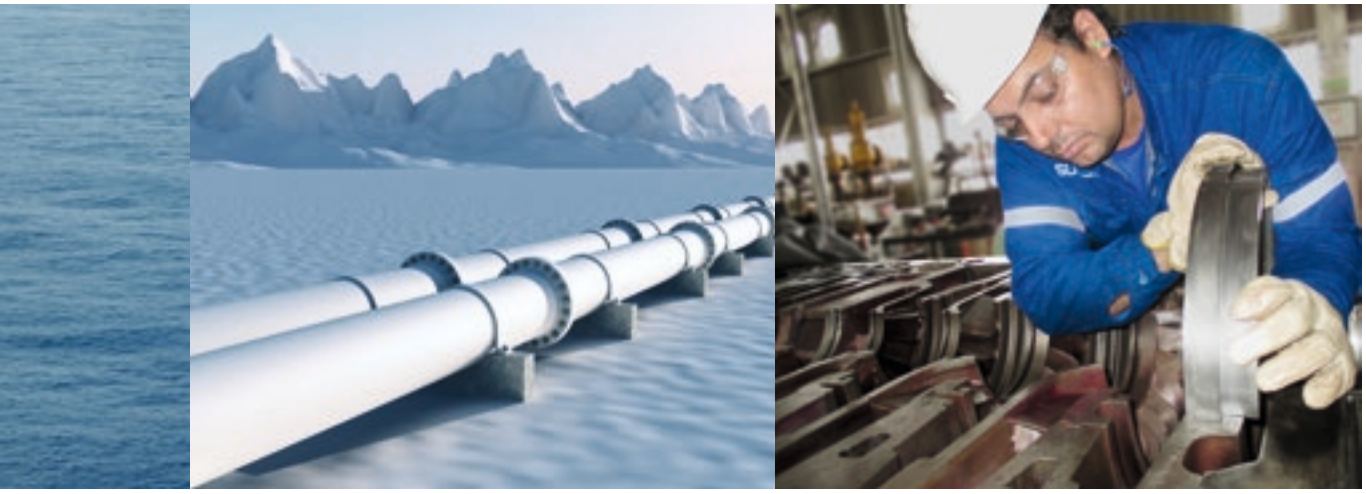
In gas production, the removal of water components from the gas is important. A comparison of the various processes that are available indicates which process is the most economical. We offer our customers these case-by-case calculations as the basis for investment decisions or retrofits (page 4). With an example from the Dunbar oil field in the North Sea, we show you how, despite falling delivery volumes, our customers are able to reduce their operating costs through innovative ideas (page 8).

Two research projects at Sulzer are examining the transport of fluids and the pipeline industry. Their goal is to create an optimal design of pumps for viscous fluids, such as oil, and thereby to sustainably reduce energy consumption and operational costs (pages 14 and 18).

Ethylene is produced following the refinery process, and avoiding downtime is of vital importance for our customers in order to save time and money. Ideal project planning and good preparation are thereby prerequisites for the high performance of our service teams (page 21).

I hope this edition delivers some interesting and inspiring reading!

Greg Poux-Guillaume
CEO Sulzer



From Recovery to Refining

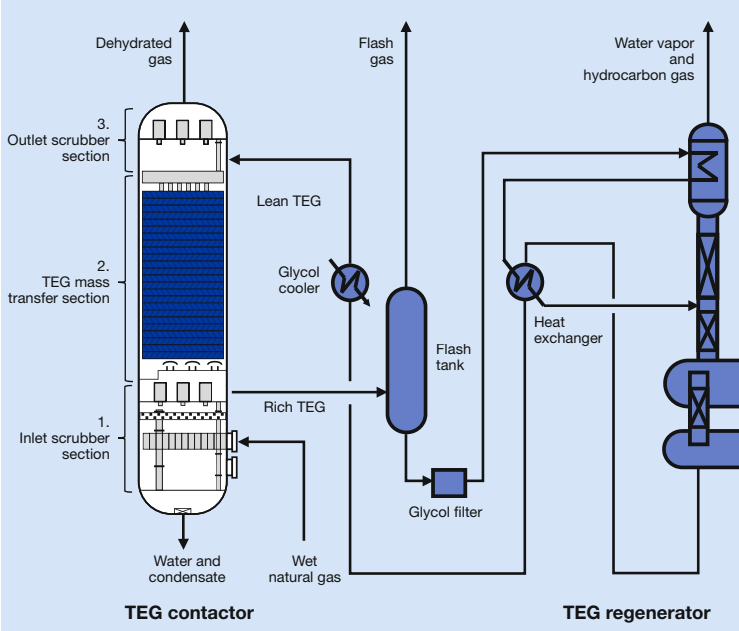
Panorama

The Evolution of Glycol Contactors

The dehydration of natural gas is an integral part of many gas processing applications. Dehydration with triethylene glycol (TEG) is effective and has been successfully employed in both onshore and offshore facilities. Sulzer has the expertise to perform project-specific evaluations that result in optimized TEG contactor column designs. Of importance is the appropriate selection and design of the mass transfer and mist elimination equipment. An optimized TEG contactor design, when determined in the early project stage, will bring significant weight, space, and cost savings.

The dehydration of natural gas is an integral part of many gas processing applications. Water can form hydrate crystals with hydrocarbons and acid gases (CO_2, H_2S). These hydrate crystals can agglomerate and cause plugging problems. Water, as free aqueous liquid, can dissolve acid gases and cause severe corrosion problems as well.

Different gas processing applications have varying dehydration requirements. Sales gas plants must meet climate-specific dew-point requirements for pipeline



2 The TEG dehydration unit, including the regeneration system.

1 Glycol contactors are employed in both land-based and offshore operations.

transmission. Peak-shaving gas plants require extreme operational flexibility in gas throughput. Deep natural gas liquid (NGL) recovery, via cryogenic processes at low temperatures, requires dehydration to extremely low levels (parts per million). The offshore dehydration near the wellhead has to consider the presence of contaminants in the natural gas. These contaminants can cause operational issues. For non-stationary vessels, such as floating production, storage, and offloading (FPSO) units, tilt and motion conditions can further affect process performance of the dehydration.

TEG contactor column

The TEG contactor is complex to design. It performs three different processes, namely: 1. mist elimination in the inlet scrubber section, 2. absorption of water in the TEG mass transfer section, and 3. mist elimination in the outlet scrubber section (Fig. 2, page 4).
The wet natural gas first enters the inlet scrubber section, where contaminants, like liquids and solids, are removed. The gas subsequently enters the mass transfer section, where water is absorbed into the TEG solvent from the gas. Finally, the gas goes through the outlet scrubber section, where any entrained TEG droplets are removed. It exits the column as dry gas.
Over the years, Sulzer has come up with four design options (Fig. 5, page 6). Each option has an appropriate combination of mass transfer and mist elimination technologies.

Feed gas composition	Value	Unit
Methane	79.55	mol%
Ethane	9.15	mol%
Propane	4.82	mol%
i-Butane	0.81	mol%
n-Butane	2.05	mol%
i-Pentane	0.50	mol%
n-Pentane	0.66	mol%
Hexane	0.33	mol%
Nitrogen	0.72	mol%
Carbon dioxide	1.16	mol%
Water	0.25	mol%

3 Natural gas feed composition for the case study.

Operating conditions	Value	Unit
Column operating pressure	80	bar(a)
Lean TEG flow rate	4 000	kg/h
Lean TEG purity	98.5	wt%
Feed gas flow rate	300	MMSCFD
Feed gas temperature	32	°C

4 Operating conditions of the TEG contactor for the case study.

TEG dehydration system

The TEG gas dehydration unit comprises more than just the TEG contactor, and it is essential to consider the overall dehydration flow scheme to achieve successful gas dehydration. The TEG solvent goes through a closed circulation loop, and water is removed from TEG in the regeneration section. The regenerated TEG solvent is reintroduced into the contactor for water absorption. TEG regeneration has profound effects on the lean TEG purity and quality of dehydration.
The TEG gas dehydration unit can experience various operational issues, including fouling and foaming. These challenges can be partly mitigated by properly designed mass transfer and mist elimination equipment.

Case study for new TEG column design

Exact definitions and calculations for the column design guarantee process reliability for Sulzer customers. The following case study compares four combinations of mass transfer and mist elimination technologies. The feed composition and conditions of the wet gas depend on the gas or oil well (Tables in Fig. 3 and 4). For comparable results of all four options, the design parameters, like lean TEG inlet stream data and column operating pressure, remain constant (Fig. 4). The dry gas specification is 4 lb. water (1.81 kg) per millions of standard cubic feet (MMSCF) gas at a dew point of –6.7 °C.
Besides the technological aspects, this case study highlights the substantial savings in column weight and size with advanced Sulzer technologies, which are especially important for offshore installations. The consequent reduction in investment costs is considerable and can affect overall project costs significantly, thus warranting column optimization studies in early project phases.

Column sizing of the TEG contactor can be compared using the F-factor, which is defined as the multiple of the gas superficial velocity and the square root of gas density. The F-factor is the appropriate parameter to compare TEG contactors, which have characteristically high gas loads and low liquid loads. The higher the F-factor, the higher the capacity of the mass transfer and mist elimination equipment is. At a fixed feed gas rate, the column diameter can be reduced.

Comparing mass transfer technologies

In the following chart, Sulzer compares four different TEG process technology options that have been developed over the years (Fig. 5).

Option 1: Until the 1980s, TEG contactors were designed with bubble cap trays. They are designed with a low F-factor of ~1.8 $Pa^{0.5}$, resulting in large column sizes.

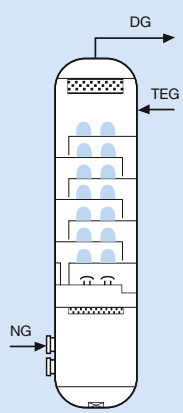
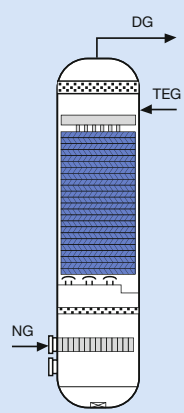
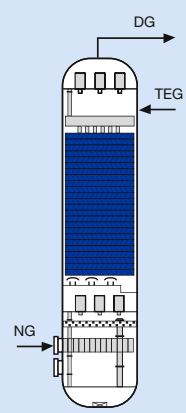
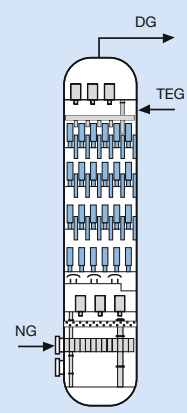
Option 2: Sulzer Mellapak™ structured packing (Fig. 6) allows the size of the column to be reduced with a higher F-factor of ~2.3 $Pa^{0.5}$. The weight and cost of the column drop correspondingly. Moreover, Mellapak confers other process benefits, including an increased operating range and lower TEG flow rate requirements.

Option 3: The second generation of structured packings, MellapakPlus™ (Fig. 7) incorporates all the advantages of Mellapak and leads to even better F-factors. By gradually sloping the corrugation angle at the packing element ends, MellapakPlus performs at higher capacities and lower pressure drops without sacrificing separation efficiency. The F-factor is doubled and reaches ~4.2 $Pa^{0.5}$. MellapakPlus offers unparalleled capacity amongst all mass transfer equipment that operates under countercurrent flow driven by gravity.

Option 4: For the ultimate capacity, the gravity limit must be broken. The Shell Swirl Tube™ Tray, part of the Sulzer portfolio, make use of centrifugal forces for gas-liquid contacting and disengagement. Shell Swirl Tube Trays are not typically used for new column designs but rather for revamps. They maximize natural gas throughput within an existing column.

Comparing mist elimination technologies

Advances in F-factors due to improved mass transfer technologies must be coupled simultaneously with

Description	Option 1	Option 2	Option 3	Option 4
DG = Dehydrated gas TEG = Triethylene glycol NG = Natural gas				
Mist elimination at inlet scrubber	Conventional wire mesh	Shell Schoepentoeter™ KnitMesh V-MISTER™	Shell Schoepentoeter™ MKS Multi Cassette™	Shell Schoepentoeter™ MKS Multi Cassette™
Mass transfer section	Bubble cap trays	Mellapak™	MellapakPlus™	Shell Swirl Tube™ Tray
Mist elimination at outlet scrubber	Conventional wire mesh	KnitMesh™ 9797-Glycol	MKS Multi Cassette™	MKS Multi Cassette™
F-factor [$Pa^{0.5}$]	1.8	2.3	4.2	5.1
Column diameter [mm]	2600	2300	1700	1550
Weight of column [%]	100	73	51	52
Cost of column [%]	100	86	62	69

5 Comparison of the four different TEG contactor design options for the case study.

improvements in the mist elimination technologies. Otherwise, the size of the mist elimination equipment becomes the bottleneck in decreasing the column size. Notably, although both the inlet scrubber and outlet scrubber perform mist elimination, the process requirements are different, and they warrant different design philosophies. The development from conventional wire mesh to optimized KnitMesh™ technology, including the V-MISTER™, improves liquid drainage and liquid handling capabilities and can offer capacity improvements. MKS Multi Cassette™ (Fig. 8) is a Sulzer-patented, hybrid mist eliminator. It combines the advantages of wire mesh and cyclonic mesh eliminators. MKS Multi Cassette offers outstanding separation efficiency and capacity, and it is competitive in terms of cost and space requirements. The F-factor of MKS Multi Cassette can be more than double that of wire mesh mist eliminators.

State-of-the-art combination

For new columns, customers do not typically install the ultimate capacity designs. Capital expenditure and flexibility in use are also considered in today's market. The MellapakPlus – MKS Multi Cassette option is the state-of-the-art combination. It results in an optimized column design together with a high F-factor, and it leads to cost-effective dehydration results.

The Sulzer MellapakPlus and MKS Multi Cassette design is also the preferred choice for offshore TEG contactors. Cost, weight, and space savings are achieved not only on the column shell, but also on the offshore platform or FPSO itself. In addition, under tilt and motion conditions, structured packing has displayed significantly lower susceptibility to maldistribution over random packing and trays. That makes MellapakPlus the ideal solution for TEG contactors on non-stationary structures.

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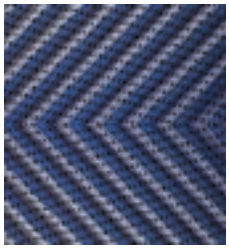
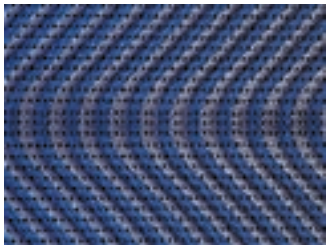


6 Sulzer Mellapak™ structured packing (Option 2).



7 Sulzer MellapakPlus™ for higher capacity with same separation efficiency (Opt. 3).

8 Sulzer MKS Multi Cassette™ (Option 3) offers high efficiency and high capacity mist elimination.

Maximize gas throughput in existing installations

For existing TEG contactors the heart of the column can be exchanged to make use of the advanced technologies. Cost-efficient revamp solutions with MellapakPlus allow customers to improve their process efficiency. A European company operating several gas-processing facilities with TEG dehydration systems refurbished all of its TEG contactors. Originally, these TEG contactors were equipped with bubble cap trays and conventional wire mesh mist eliminators (Option 1). Thanks to good results, they have been gradually upgraded to Sulzer MellapakPlus 252.Y structured packings and MKS Multi Cassette mist eliminators (Option 3). The customer appreciates that this solution offers increased natural gas throughput and greater operating flexibility, while it also meets all product specifications.

One of the customer's TEG contactors was initially processing 134 million standard cubic feet per day (MMSCFD) of natural gas. After the upgrade to MellapakPlus 252.Y and MKS Multi Cassette, the TEG contactor is able to achieve the new target capacity of 224 MMSCFD — an increase of 67% over the original design basis. It is worth further noting that this TEG contactor can potentially process 315 MMSCFD of gas, which is a 135% increase from the original design basis.

Successful Dunbar Field Life Extension

The advent of high-power multiphase pumps is changing the world of oil production. In particular, they allow continued production from fields that are nearing the end of their useful lives. These revolutionary pumps have been in operation since autumn 1999 on the Dunbar platform, in the UK sector of the North Sea.

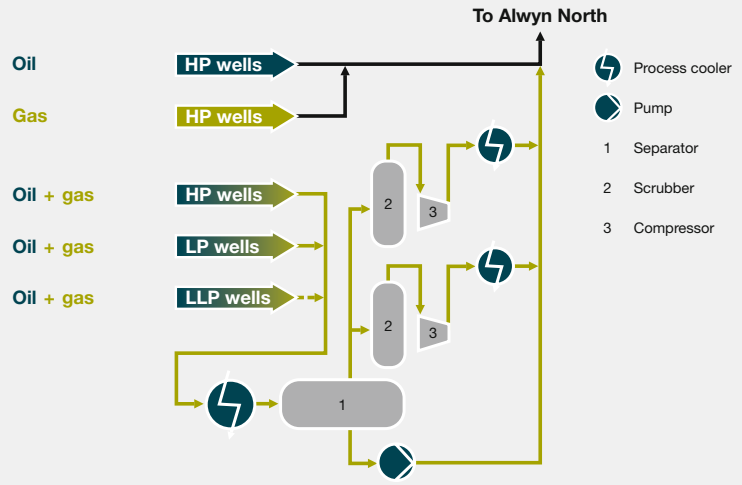
Multiphase pumping (MPP) is essentially a means of adding energy to the unprocessed effluent. This technique allows the transport of gas and liquid mixtures over longer distances without the need for prior phase separation. It also empowers the wells to produce at a lower wellhead flowing pressure (WHFP). Thus, the production and ultimate recovery from existing fields and weak wells increase. The life of a field can be extended and development costs can be reduced. The Dunbar field, operated by Total, is a perfect example of how these benefits have been realized in practice.

The Dunbar field in detail

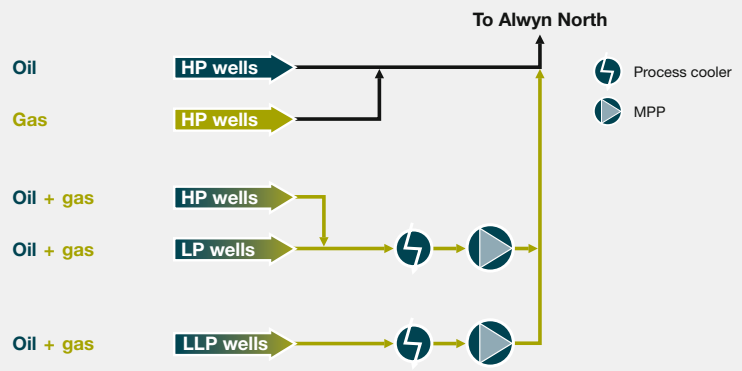
The Dunbar field is located 120 km northeast of the Shetland Islands and 440 km from Aberdeen, UK. Dunbar is a wellhead platform that is operated as a satellite of the Alwyn North Platform located 22 km to the northeast. In the first phase of production, the wellhead pressure was sufficient for the effluent to flow naturally from Dunbar fields along a 16-inch multiphase pipeline to the Alwyn platform (Fig. 1). The introduction of multiphase pumps in Dunbar allowed production to continue in the face of declining well-head pressure.

Minimizing space and weight with MPP

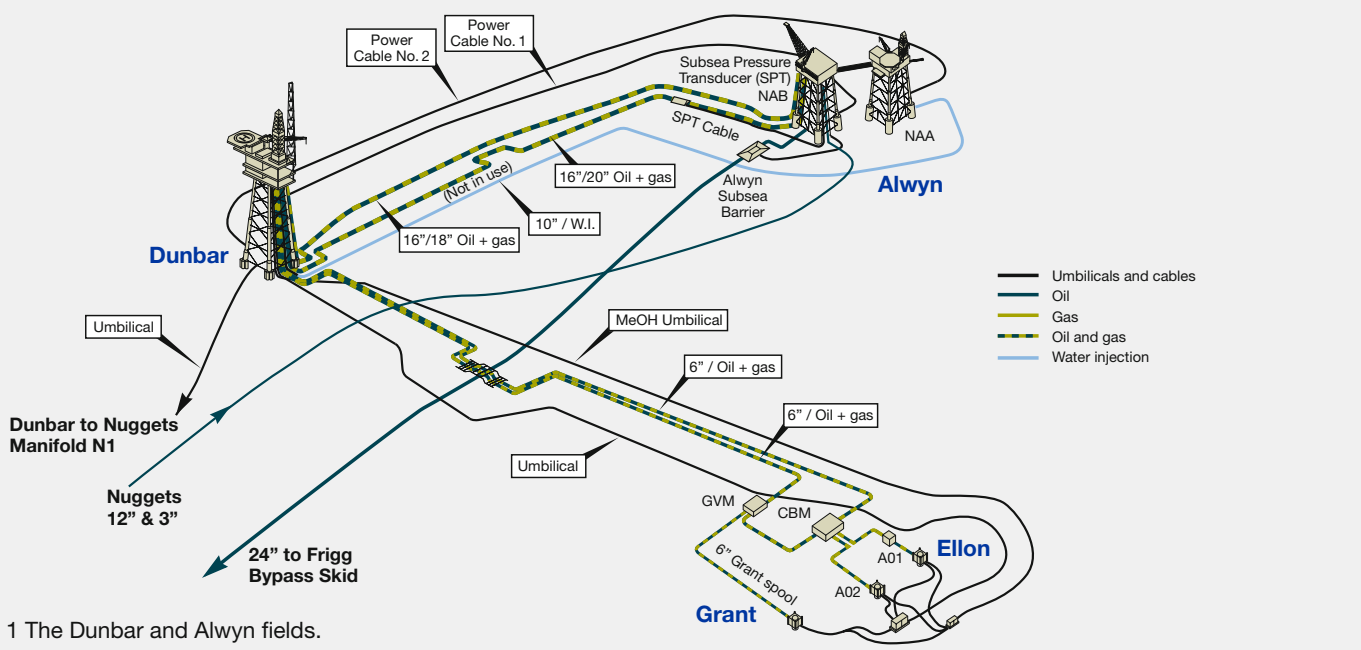
The operating company considered two main alternatives to develop their field. One was a conventional system (Fig. 2) that comprised a separator operated at low pressure with the liquids pumped and the gas compressed upstream of the multiphase pipeline.



2 Conventional concept.



3 Innovative concept using multiphase pumps.



1 The Dunbar and Alwyn fields.

The other was an innovative system (Fig. 3, page 9) that used MPP to combine several wells and boost the low-pressure wells directly into the multiphase pipeline. Why did the operating company select the Sulzer MPP solution over a separator-based solution? Weight and space restrictions on the Dunbar platform favored the design of the MPP cantilevered module extension. This module was over 30% lighter than a conventional system. Installing the pumps vertically minimized the space requirements. There were no major modifications required to the existing process facilities other than tying in the MPP.

Smart well segregation scheme

A well segregation scheme provides operational flexibility. This scheme of three independent production headers — high pressure (HP), low pressure (LP), and low low pressure (LLP) — makes maximum use of the natural energy of the wells. This minimizes the electrical power requirements. HP wells bypass the pumps. LP and LLP wells are routed to one of the two MPP to maximize production. In the early years of MPP operation, this routing was based on the wellhead pressures (see LP and LLP wells in Fig. 3). In recent years, other factors — such as gas-to-liquid ratio and water production — have also influenced the routing. At present, about 20 wells are routed to the MPP; there are plans to route other wells there in the future to accelerate production.

4 Inside the module is the Dunbar multiphase pump.

Offshore installation

In 1999, the largest offshore multiphase pumps in the world were installed on the Dunbar platform. No other offshore multiphase pump is larger, even today, in 2016. The two pump packages were incorporated into a module at the fabrication yard. The module, which is 12 x 7.5 x 19 meters (LxWxH) in dimension, weighs 650 tons (Fig. 4). Sulzer and ABB worked as partners to supply the pump set packages. Each pump set comprises the following main items: Process cooler, buffer tank at pump section, Sulzer multiphase pump, epicyclic gearbox, lube oil and seal oil systems, electric motor and frequency converter, transformer and antiharmonic filters.

The design parameters of the pump in use are:

- Total capacity 180 000 barrels per day (bpd)
- Gas volume fraction GVF 75%
- Speed range 3 500 to 6 000 rpm
- Motor rating 4 500 kW

MPP design upgrades

The reducing Dunbar wellhead pressures over time increase the ratio of gas-to-liquid flow rates. This produces liquid slugs that cause MPP instability, particularly, increased subsynchronous vibration, which sometimes causes MPP trips.

Sulzer R&D center located in Winterthur, Switzerland, dedicates considerable effort to developing new solutions for MPP. The charts (Fig. 5 and 6, page 11) show the reduction in subsynchronous vibration resulting from a revised balance drum design. The influence on vibrations is remarkable. Fig. 5 shows vibrations with the conventional balance drum, Fig. 6 with the revised balance drum.

Good collaboration between Sulzer and Total made it possible to apply these improvements to the Dunbar MPP in 2013. This helped to improve the stability of the pump. Three mechanical modifications to the pump led to success. A redesign of the balance drum provides additional damping of the Dunbar MPP rotor on the balancing machine. Significant changes to the manufacturing process for hollow shafts provide additional stiffness and better pump rotor-dynamic behavior. The installation of a Sulzer-patented damping device on the shaft provides additional damping.

Improved control reduces vibrations

The pump can either run in manual or automatic mode. In manual mode, the operator adjusts the speed by hand to maximize the production while maintaining the pump within its preferred operating range.

Sulzer improved the control system of the MPP by developing an automatic mode. In this mode, the operator defines a torque set point, and the pump speed is adjusted by software automatically to reach this set point. Automatic torque control dampens liquid slugs to minimize pump vibration. These modifications together with good management of well routing allow further reduction of wellhead pressures and increased MPP availability of over 90%.

Evolution of process conditions from 1999 to 2016

The exhaustion of the Dunbar wells has led to a significant decrease of the wellhead pressures (Fig. 7). These pressures have dropped from a pressure of 70 bar(g) in 1999 to a pressure of less than 30 bar(g) in 2016. The discharge pressure required has also decreased — from about 125 bar(g) to 62 bar(g). Consequently the inlet gas volume fraction (GVF) has increased from 77% in the early days to 90–92%. Thanks to the wide range of operation of the helico-axial hydraulics, the pump is still in operation with the same hydraulic design it had in 1999.

The flexibility of the Sulzer MPP will help the company Total E&P UK optimize late-life production from the Dunbar reservoir. Wellhead pressures of 20 bar(g) and below can be processed in the future without the need for significant investment.

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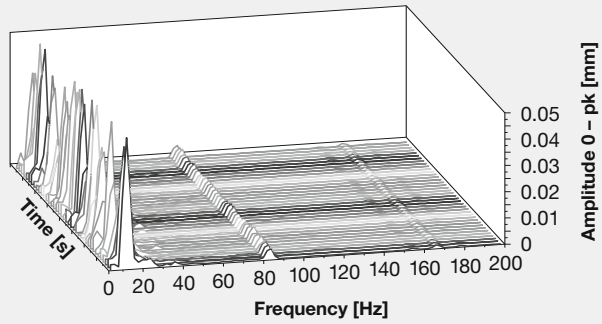
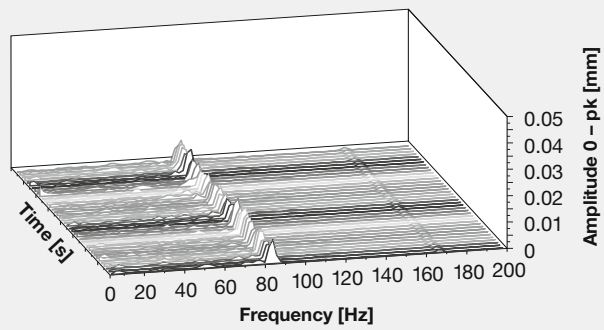
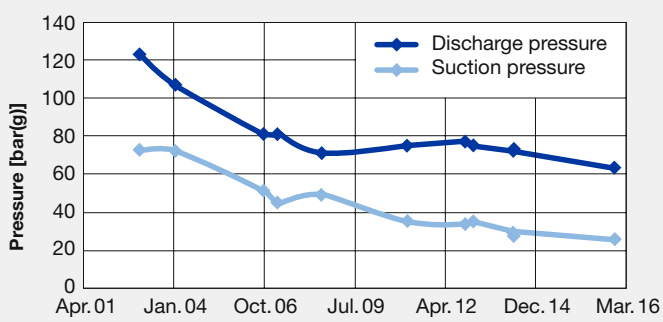


5 System vibrations with conventional balance drum.



6 Reduced system vibrations with revised balance drum.



7 Pressure development at Dunbar field over the years, measured at multiphase pump G2100B.

Innovation in Offshore Separation Process

CLOV is a deep-sea oil production project offshore Angola. Sulzer helped to lower the cost of the floating production, storage, and offloading (FPSO) ship. There, Sulzer's patented distributor technology and state-of-the-art pumps are brought to life by Total's innovative wash tank process. This combination achieves significant cost savings on the FPSO design.

With a processing capacity of 160 000 barrels per day of oil and 230 million cubic feet per day of natural gas, CLOV is one of the largest FPSOs in the world. The CLOV FPSO, operated by Total, is 305 meters long and 61 meters wide.

Innovative oil-cleaning process

Thanks to Sulzer's high-performance separation technology, the oil-cleaning process achieves commercial oil specifications with processing tanks integrated into the hull of the FPSO vessel. Water and salt are removed from the oil in the wash and desalting tanks. For this cleaning process, Sulzer designed innovative static mixers and inlet distributors.

Design studies performed by Sulzer for CLOV

Sulzer performed a design study for a preliminary sizing of the mixer and inlet distributor. Two key design aspects helped to meet the target performance of the wash tank process:

- The static mixers, which provide optimum mixing of the oil/water phases.
- The inlet distributors, which optimize the use of the separation section in the hull and improve the water-in-oil content at the tank outlet.

A computational fluid dynamics study (CFD) was performed to understand the influence of FPSO motion on the tank and separation process. The results of this CFD analysis helped to finalize the design of the

1 The CLOV FPSO is 305 meters long and 61 meters wide.

2 Liquid distributors for wash tank process.

3 Sulzer BB2 pump set for the CLOV project.

static mixers and inlet distributors. The internal elements that Sulzer designed create optimally sized droplets of oil. Thus, better separation is achieved even under motion conditions. The technology lessens the required topsides equipment, which leads to significant weight reduction and makes it ideal for an FPSO installation, where it benefits from the large hull size.

Sulzer was able to draw from its extensive experience for this FPSO application, including:

- Pilot plant tests, under both static and motion conditions, dating back to the 1980s.
- Understanding instrumentation, sand handling, and mechanical arrangements for the offshore environment.
- Cooperating with the Technical University of Berlin to test various wash tank distributor geometries to achieve best possible water/oil separation.

The construction of the CLOV FPSO was completed in 2014, and oil production started successfully. The technology has been in operation also on Usan and Pazflor FPSOs, and it will be delivered to Moho Nord floating production unit (FPU), Martin Linge floating storage and offloading ship (FSO), and Egina FPSO; all being assets operated by Total.

Pumping solutions for critical services

Total selected Sulzer to provide pumps for the CLOV wash tank process. In addition Sulzer supplied all of the topsides process pumps including the water injection system. These pumps are expected to operate continuously in the topsides of the FPSO. Therefore, they are subject to the pitch and roll movements of the ship, and they have to withstand challenging operating conditions. Sulzer pumps are designed for use in harsh offshore environments and are compliant not only with the basic API (American Petroleum Institute) standards but also with more-exacting specifications of Total.

To the CLOV FPSO, Sulzer delivered two BB5 water injection pumps (8 MW variable-speed-driven, high-pressure barrel casing pumps). Sulzer also supplied all of the topsides API 610 process pumps including large BB2 pump sets that deliver deaerated seawater to the sulfate removal unit membranes to treat the seawater prior to injection. These API 610 pumps are employed for critical services ranging from dead oil circulation and delivering cooling and heating media across the entire topsides, plus process duties in the oil train to separate and treat the crude oil before its transfer to shore.

Sulzer has also delivered critical API 610 pumps, including the wash tank BB2 transfer pumps, to similar Total projects executed since CLOV, including Moho Nord FPU, Kaombo FPSO, Martin Linge platform and also Egina FPSO, currently under construction in the SHI shipyard at Goeje Island, South Korea.

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Field Performance Testing for Pipeline Pumps

Significant energy savings can be achieved by optimizing pump operating efficiency. Measuring the exact pump performance with crude oil under realistic conditions in the field is the first step towards improving the pump efficiency in the future.

About 20 billion barrels of crude oil were transported through pipelines in 2015. Around the world, there are over one million kilometers of crude oil pipelines. In the United States alone, there are over 100 000 kilometers. More than 60 000 pumps provide the hydraulic power needed to propel crude oil through these pipelines. About 150 gigawatts are required to drive all the pumps; that equals the annual power consumption of 20 cities the size of New York. There is a large potential to save energy during the entire lifetime of the pump by optimizing the pump operating efficiency.

Pipeline Research Council International PRCI assigned Sulzer

Currently, there are no universally standardized test procedures in place to determine pump efficiencies of pumps installed in the field. In 2014, Sulzer started developing a field pump performance testing procedure for crude oil pipeline pumps under contract of the Pipeline Research Council International (PRCI). Many leading pipeline companies from around the world are PRCI members. The PRCI is a research organization dedicated to developing improved pipeline safety, reliability, environmental protection, and efficiency.

Correction factors for the industry

Normally, high-flow and high-powered pumps are used to move crude oil through pipelines. Customers need their pumps to meet the requirements of API Standard 610, which specifies the hydraulic performance acceptance tests be done according to the International Standards Organization (ISO Standard 9906) with water and not with viscous fluids. The pipeline pump performance is influenced by the crude oil viscosity. Therefore, the Hydraulic Institute (HI) has established a set of empirical formulas to calculate the pump performance with crude oil based on the pump performance with water. The HI Standard 9.6.7 "Effects of Liquid Viscosity on Rotordynamic Pump Performance" gives viscous corrections based on a significant number of tests — although based on much smaller pumps than generally used in the pipeline industry. These empirical corrections have been extrapolated for larger pumps, but there are still significant deviations. Because of this inexact viscous correction, larger pumps and drive systems may be either over- or undersized. Only an accurate performance test of these large pumps on viscous fluids would help to eliminate these potential errors. Reproducible testing needs suitable procedures that can be applied properly and repeatedly. The procedures that are developed should suit large, high-volume centrifugal pumps of any type in pipelines transporting crude oil.

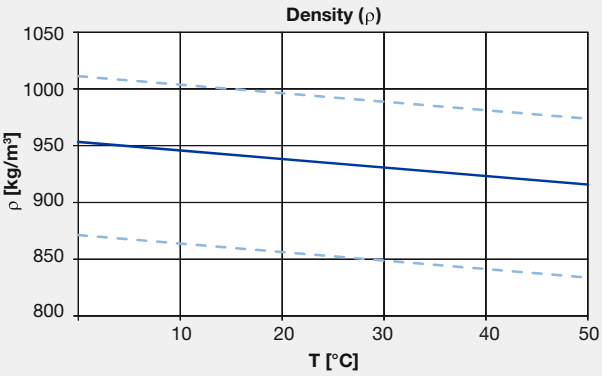
Installation of testing equipment

At remote pumping stations, not all instrumentation for testing is always available on site. Gaining access to install the needed measurement instruments in an existing pipeline filled with a flammable fluid requires

It is known that honey changes viscosity at different temperatures. Crude oil density and viscosity also varies greatly from batch to batch and with temperature. Therefore, accurate density and viscosity have to be measured for each batch. These measurements must be taken at the pump and flow measurement device. If the density and viscosity are measured at another location, they can be corrected for site temperature and pressure with the following formulas for density and viscosity.

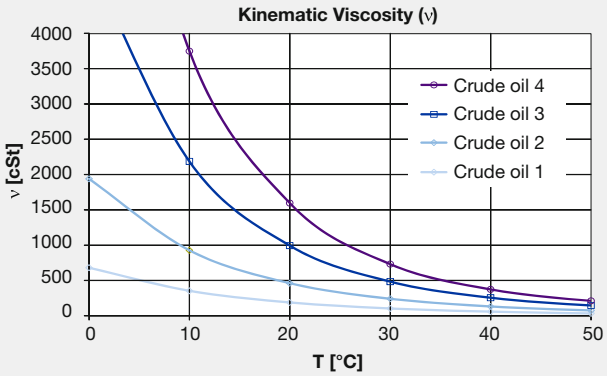
Formula for density correction as a function of temperature

$$\rho_{TP} = \rho_{ToPo} \cdot (1 + \xi \cdot (T_0 - T)) \cdot (1 + \beta \cdot (P - P_0))$$



Formula for viscosity correction as a function of temperature

$$\nu_T = \nu_{T_0} \cdot e^{(-a_\nu \cdot (T - T_0))} \cdot \left(1 + b_\nu \cdot \nu_{T_0} \cdot (T - T_0) + c_\nu \cdot \nu_{T_0} \cdot (T - T_0)^2\right)$$



1 Correction factors for density and viscosity in relation to temperature of crude oil.

special permissions and approvals. The execution demands the highest degree of caution. Penetration into the main pipe may be needed to install the different instruments (pressure, temperature, density, and viscosity measurement devices).

Crude oil density and viscosity vary along the pipeline (Fig. 1, page 15). It is mainly dependent on temperature but also on pressure. Accurate crude oil density at the pump is needed to determine pump power and efficiency. Engineers need to know the crude oil viscosity so they can compare the pump field performance with the factory test performance with water. Sulzer is testing inline density and viscosity sensors for these measurements. Flow measurements are normally not available at remote pumping stations. When installing a flow meter or a verifiable strap-on ultrasonic flow meter, engineers need to make special accommodations to secure them for proper measurements.

The pump input power measurement requires special testing equipment as well. Pumps are generally driven by electric motors, gas turbines, or diesel engines. Preferably a torque meter — installed at the pump coupling — is used to measure the pump input power delivered from the drive unit. If the pump is driven by an electric motor, the pump input power may be determined using the motor efficiency and an accurate electrical power measurement. Access to the electrical cabinets in the pump station is necessary to measure electric power. However, access to these cabinets requires special permissions for safety reasons.

Correction methods to be developed

Even if the instrumentation exists or if it can be installed, the geometrical conditions might not meet the testing standards (e.g., ISO 9906, HI 14.6, etc.). Therefore Sulzer has adapted measurement correction factors for the following field situations, which differ from in-house testing:

- The pressure transducers are not in a straight pipe section (Fig. 3 and 4) as required by pump testing standards (Fig. 2).

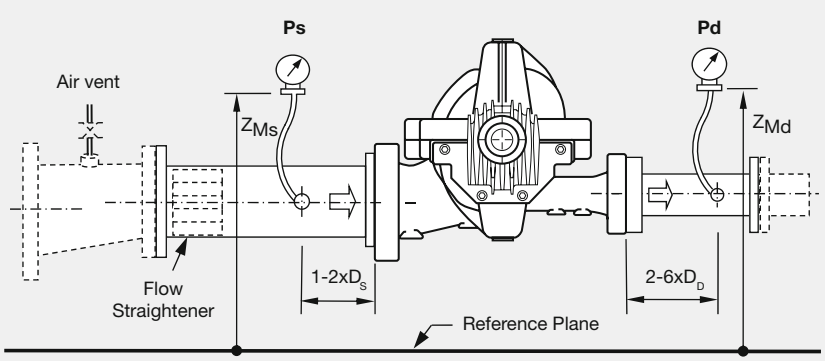
$$H_L = \sum_{i=1}^{n} \left(f_{si} \frac{L_{si}}{d_{si}} + K_{si} \right) \cdot \frac{c_{si}^2}{2 \cdot g}$$

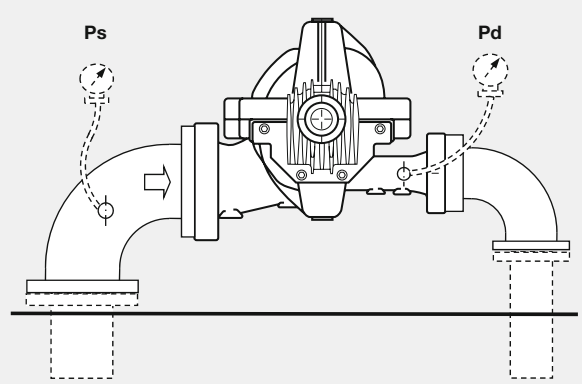
- The electrical power is measured farther away from the electric motor (Fig. 4) than under test circumstances (Fig. 2).

$$P_{MotorIn} = P_S - 3 \cdot I^2 \cdot (R \cdot \cos\phi + X_L \cdot \sin\phi) \cdot \cos\phi$$

- The density and viscosity measurements are done distant from the pump.

Suboptimal conditions must be corrected, and these methods are developed in the project as well. The overall goal of a test is to generate a pump performance curve under realistic conditions. To achieve this, the pipeline operators will need to vary the flow preferably over a range between 60–120% of the pump best efficiency point (BEP). If this is not possible, the measurement should be done with a flow range between 80–110% of the pump BEP. Pump BEP must be captured to compare field pump performance to factory tests with water.





D_S and D_D — pipe nominal diameter for suction and discharge piping respectively.

2 Test arrangement in laboratories with straight flow.

3 Typical pipeline installation.

Pump performance values taken with viscous fluids cannot be corrected using pump affinity laws because of the variance in drag forces associated with viscous fluids and Reynolds number. For this reason, the field performance test needs to be carried out at a relatively constant speed and with constant fluid density and viscosity across the full flow range tested.
Additionally, the pump operating condition in the field must be reviewed in case the field performance data has to be compared to the factory performance test data. Any operating differences from the factory test need to be reconciled, including the use of seal systems, use of bypass cooling, potential wear of the pump, or maintenance or design changes. These effects can be corrected by reconciling the volumetric efficiencies.

Research on actual testing capabilities

Sulzer surveyed liquid pipeline companies to determine the gaps between factory and field-testing capabilities. After the survey, Sulzer engineers visited some pipeline pumping facilities. They performed audits to further assess existing conditions and define realistic requirements under which a field pump performance test could be carried out. The finding of visits was that each site would require a pretest audit to clarify the site-specific requirements prior to a field pump performance testing.

Cross-checking the concept

Proof of concept measurements are currently running. The concept testing is being performed at the Sulzer's test bed in Switzerland (see page 18). Goal of this concept testing is to corroborate whether the procedure and testing methods are producing proper data — a kind of cross-check in a controlled environment. Following the proof of concept testing in the test laboratory in Winterthur, the actual field performance tests on crude oil pipeline pumps will be performed as a final confirmation of the procedure.

Customers benefit from field tests

The field pump performance test procedure currently defined and developed by Sulzer under contract of PRCI will provide a practical methodology for testing the pump performance with viscous fluids on site. The results of the tests on site and in house will provide the base for corrective calculations. In the case of deviations from the ideal measurement conditions, the corrective calculations minimize the uncertainty of the pump performance test results. Sulzer will gain more-accurate and more-comparable pump performance test results with viscous fluids than were previously possible with factory performance tests using water. The benefit of the detailed testing results will help the industry to improve pipeline operation and reduce its energy consumption.

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4 Measuring the pump efficiency in the field.

Pipeline Research Council International
PRCI Project No.: CPS-7-10
"Development of Field Pump Performance Testing Procedure"
Catalog No.: PR-471-14207-R01
Committee: Compressor and Pump Station

Download from www.prci.org

Viscous Pumping in Focus

The performance of a pump is influenced when it handles viscous fluids such as crude oil. For the configuration and design of pumps, this is key.

In the industry, pump performance curves are developed by testing with water at temperatures around 25 °C and corrected to a specific gravity of one. Engineers use this standard so that they have comparable measurement values around the world.

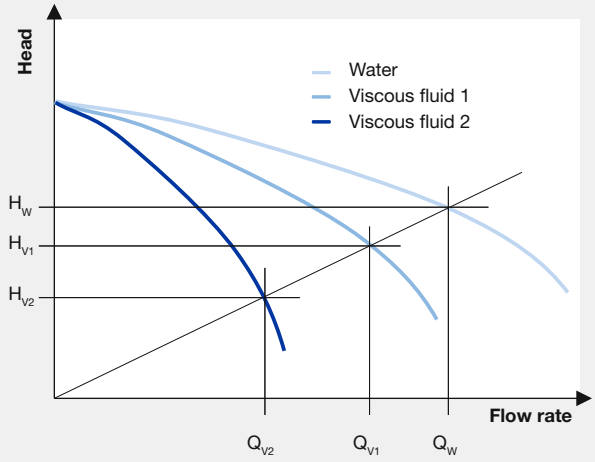
The performance of a pump is impacted, when it handles viscous liquids, such as oil. This starts to be significant when industrial installations are pumping liquids with viscosities above 40 centistokes (cSt). It can be substantial when the viscosity reaches 300 cSt or above. For a midsize pump transporting 1 000 m^3/h of oil with a viscosity of 200 cSt, the efficiency will drop to three-quarters of the efficiency achieved when pumping water. At the same time, the dynamic head will decrease by a little more than 6% at its best efficiency flow rate in water (Fig. 1, H_W and H_{V1}). Consequently, its corresponding flow at the best efficiency with viscous fluid is also reduced by an equivalent amount. This drop in performance is caused mainly by the higher friction of the viscous fluid within the hydraulic waterways of the pump. If the flow rate and viscosity increase, the performance impairment of the pump performance rises as well.

Test bed in Winterthur, Switzerland

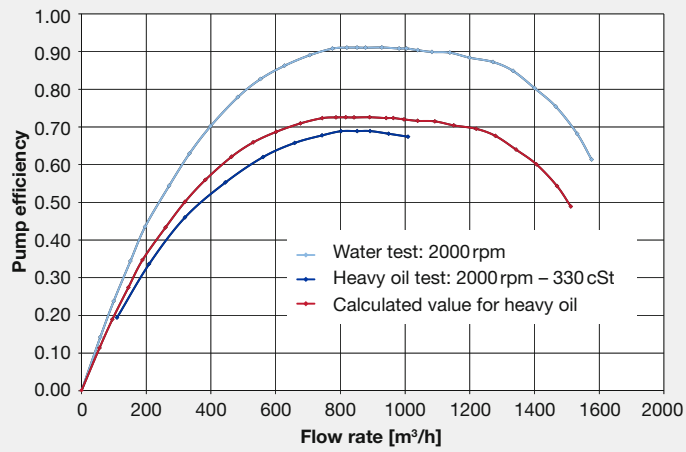
Antonio Morisco, Head of the development test bed team in Winterthur speaks about the many different testing loops available in the 1 500-square-meter facility located in Switzerland. “Our impressive test bed inspires the dreams of many of our visitors. However, you can be sure that we are not giving our test team or equipment any time to sleep.”

He points to the five-meter-high installation full of pipes, cables, and various measuring instruments. “We perform tests under different conditions to gather technical values related to viscous flow behavior in the pumps. With our viscous test loops, we evaluate pump efficiency in relation to the viscosity of the pumped fluid. First, the values of our test bed are used to realistically confirm pump capacity for our customer projects. Second, our R&D department uses the test bed to evaluate and improve the pump performance and energy efficiency. This test bed has already seen pumps with different coatings, bearings, and hydraulic shapes in all sizes. Our tests also show whether our development leads to the expected energy savings.”

Antonio Morisco in front of the test bed installation for viscous pumping.



1 Head and flow rates with fluids of different viscosities.



2 Comparison of measured and calculated pump efficiency/flow rate values.

The correct correction factor is crucial

Having an accurate prediction of the pump efficiency curve is essential if one wants to make the best selection of the pumps and their drives for viscous pumping applications. Several years ago, the Hydraulic Institute (HI) developed correction factors for viscous liquids. These correction factors enable engineers to predict the performance impairment with viscous applications relative to the water performance curves that are usually published by the pump manufacturers. The current HI standard is ANSI/HI 9.6.7-2010 "Effects of Liquid Viscosity on Rotodynamic Pump Performance" and is widely accepted. Lately, however, an increasing number of publications have been reporting discrepancies between the performance rates predicted according to the ANSI/HI 9.6.7 standard and those that are measured with viscous fluids.

The correction factors developed by the Hydraulic Institute are based on tests with pumps of small power levels. Furthermore, they are generated with pumps mainly of the single-stage overhung type rather than with the pumps of the large power double-suction single-stage or multistage between bearing type usually used in viscous applications. These differences are likely responsible for the discrepancies.

Deepened know-how in viscous pumping

Sulzer has upgraded two loops of its development test bed in Winterthur so that it can examine pumps with single or multiphase viscous fluids up to 2 000 cSt. Sulzer runs intensive test campaigns with single-stage, double-flow pumps, typically used in pipelines, or multiphase helico-axial pumps, typically used to boost oil production. Sulzer R&D department collects essential know-how with these tests regarding the causes of performance impairment with medium- and high-viscosity fluids as well as the impact of specific pump design features. The results of these in-house tests highlight the need to refine Hydraulic Institute's viscous correction factors in the future. They must better account for the pump types used in the petroleum industry today.

Identifying the influencing factors of the future

The pump performance rates measured for a single-stage, double-flow pump with a fluid viscosity of 330 cSt (Fig. 2) indicate the following: the measured performance impairment due to the viscosity of the fluid is higher than the one calculated using the HI correction method. Sulzer tests different design parameters for pumps that transport viscous materials. Thereby, Sulzer always keeps the pump efficiency and, thus, the energy consumption of the pumps in mind. Sulzer's systematic trials at the test bed, combined with field tests at customers' sites, will pave the way to innovative solutions for pumping viscous fluids.

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How the Earthworm Improves the Soil

Nature has ways of converting vegetable and mineral raw materials into high-quality products. The inconspicuous earthworm provides striking example — it is a minirefinery in the soil.

The dew worm or common earthworm, which is native to Europe, is just one of more than 3000 earthworm species in the world. About 30 centimeters long, the powerful earthworm digs vertical burrows many meters down into loamy, sandy soils. To collect organic material, it comes to the surface in the dark because its pale body is poorly protected against UV radiation. It also has to keep its skin moist, which is why it prefers to move about in rainy weather to look for a partner or to change its burrow.

Modern investigations have confirmed the usefulness of earthworms: in healthy meadowland, up to 500 earthworms work per square meter of ground and produce up to 60 kilograms of humus a year. Earthworms perform high-quality recycling and refining of plant and animal residues in their gut.

Microbes aid digestion

The worms cannot chew, nor do they have enzymes with which to dissolve the cellulose and the lignin of the plant cells and to access their nutritious content. Instead, they suck on leaves or stalks lying on the ground, pull them into their burrows, and let bacteria and fungi break down the cells there.

Only after the preparatory work of these microhelpers do the worms suck in the food, including the nutrient-rich microorganisms. Along with the food they ingest, the earthworms consume mineral particles from the soil, which then act as an abrasive powder in the gizzard and thereby grind the food into a fine pulp. The food is chemically decomposed in the intestine, allowing the worm to absorb the nutrients into its bloodstream through the intestinal wall. It deposits everything undigested at the entrance of the burrow as excrement.

High-quality fertilizer as the end product

The earthworm can only extract five to fifteen percent of the nutrients from the food: most of the nutrients thereby return to the surface in the feces. There, bacteria, insect larvae, and springtails immediately pounce on the nourishing remains and release more nutrients. This is then an invitation for the earthworm to take in its own, refined excrement once again. In this way, the same nutritious pulp passes through the earthworm's gut repeatedly, continually supplemented by new minerals, plant remains, and microorganisms. The earthworm excrement becomes a high-quality mixture of organic and mineral substances in a form that plants can readily absorb — substances that have been refined in multiple working steps.

Increase in yield thanks to earthworms

The importance of this soil-biological potpourri for the growth of plants has been shown by studies in Holland, where earthworms were introduced into newly reclaimed land. Thanks to the help of the earthworms, the winter wheat yield doubled, and the clover yield increased tenfold compared with new fields without earthworms.

Author: Herbert Cerutti

1 A Sulzer technician installing seals on the compressor.

Overhaul Completed in Just 30 Days

Sulzer completed an overhaul of three General Electric steam turbines and five Clark compressors for a large ethylene plant in Colombia. Sulzer's service centers in Texas and Bogotá worked together to inspect and repair the three turbines. Sulzer staff helped the customer with project planning, full commissioning, and testing within a very tight timeframe.

A daily production of 144 tons

The city of Barrancabermeja is known as the "oil capital" of Colombia — a good location for an ethylene plant. The customer's mill can produce 44 000 tons of ethylene and 8 800 tons of propylene per year — which equates to 144 tons per day. Such mills run continuously. It is of vital importance that regular, preventive maintenance is performed to keep the installations running reliably and at maximum efficiency. To minimize production losses, the time for maintenance breaks must be as short as possible. For its steam cracking process, the plant in Barrancabermeja employs steam-powered turbine compressor trains before the distillation phase of processing the gases.

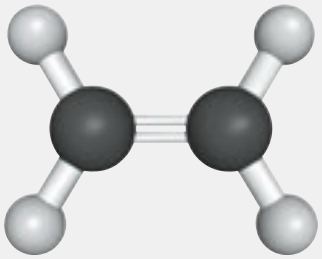
Planning started one year ahead

Carrying out maintenance during a planned outage on time and within budget requires considerable planning and careful management throughout. Since 1999, the Colombian mill relied on Sulzer's expertise in the repair of turbomachinery equipment. The customer initially contracted Sulzer to perform all the planning activities for the compressor deck during the outage and to inspect and repair the spare set of rotors. Sulzer exchanged the running compressor rotors with the shop repaired spare units which were repaired in Houston before, to allow fast turnaround during the outage. Subsequently, the customer also asked Sulzer to carry out all the compressor deck activities during the outage. All of this work had to be completed within 30 days.

Ethylene — the world's most-used organic compound

Ethylene, also named ethene, is a colorless, flammable gas. It is widely used in the chemical industry. The global production of ethylene exceeds that of any other organic compound. More than half of the ethylene supply goes toward making polyethylene, which is the world's most widely used plastic. Polyethylene is used to make films in packaging, carrier bags, and trash liners.

Ethylene is often produced in the petrochemical industry by steam cracking. This process converts large hydrocarbons into smaller ones and introduces unsaturation. In steam cracking, gaseous or light-liquid hydrocarbons are heated to 750–950 °C. This initiates numerous free-radical reactions. These reactions only take place briefly. Once the cracking begins, the gas is immediately quenched to stop these reactions. Ethylene is separated from the resulting complex mixture by repeated compression and distillation. Other methods produce ethylene by using naphtha or gas-oils.



Ethylene has the formula $H_2C{=}CH_2$.

2 Ethylene is the base for many packaging products, such as PET bottles.

Designation	Brand	Model	No. of stages	Speed [rpm]	Power / volume flow
NC-4100	GE	DRV-M	7	7522	6.96 MW
C-4100A	Clark	3M9-7	9	7522	4446 m^3/min
C-4100B	Clark	2M10-8	10	7522	98 m^3/min
C-4100C	Clark	2M8	8	7522	53 m^3/min
NC-4101	GE	DRV	10	3871	9.4 MW
C-4101	Clark	4M10-8	10	4226	693 m^3/min
NC-4102	GE	DRV	5	8292	1.36 MW
C-4102	Clark	2M10-9	10	8292	94 m^3/min

3 Compressor trains for the rotor exchanges done by Sulzer.

Those who have ever organized a wedding or similar event know how much time is required to plan a one-day event and how much discipline it takes to keep activities within a budget. Imagine how much time it takes to plan a 30-day overhaul with 12 service technicians. Sulzer deployed two project managers during the planning phase to provide a project execution plan and an overall schedule. The planning started over a year ahead of the actual work.

Excellent project management

One of these project managers was José Saldana, a talented young engineer who speaks fluent English and Spanish. “The project manager is responsible for the smooth workflow of the whole project. One important planning step is to break down the overhaul maintenance work into sequences of work. Then we list all requirements for this sequence, timeframe, and how many people are needed to manage the project on time.”

Uncertainties have to be considered in planning as well. Saldana explains, “Jesus Leotaud, the project manager from the Sulzer Bogotá office, always checked whether the equipment and spare parts we needed were on hand in the right quality at the customer’s warehouse. We also checked whether tools, lifting devices, or cranes were available. Such detailed planning has to consider budget aspects so that the team can complete projects safely, on time, and within budget.”

Furthermore, good communication is vital. Saldana continues, “When the overall schedule was set up, we also established a communication plan. People underestimate how important communication is for the success of a project. Downtimes are very often caused by a lack of communication or by uncertainty about the line of communication. It is important for project leaders to speak the local language.”

Compressor deck arrangement

With the working schedule established, Sulzer assigned a team of 12 field service technicians to complete the maintenance project. The ethylene plant uses several General Electric steam turbines to drive a series of Clark (today Siemens Dresser-Rand) compressors — all common equipment within the petrochemical industry and very familiar to the Sulzer engineers.

The compressor deck arrangement in this project consists of two turbines each powering single compressors and a third turbine running a train of three compressors. Each arrangement has a unique setup and operating specifications, which are detailed by the original equipment manufacturers (OEMs). Each piece of equipment has a unique designation that ensures that all the information relating to its maintenance and setup is recorded correctly and that the right spare parts are stocked. The compressors are designed to take the cracked gas from an intake pressure of around 1.3 bar (19 psia) to a discharge pressure of around 35 bar (510 psia), having passed through 47 stages of compression (Fig. 3).

Overhaul and testing in Houston

The spare rotors that were prepared and installed by the Sulzer Field Service team had been previously remanufactured at the Houston facility; each component had been brought back to engineering specification. “Houston is our flagship repair center.” José Saldana adds, “We have a systematic approach with checklists for each remanufacturing order. Starting with an initial

4 Balancing at the Sulzer shop in Houston, TX, USA.

High-speed balancing bunker in Houston

Rotor weight capacity:	25 tons
Max operating speed:	40 000 rpm
Max rotor length:	7.11 meters
Max rotor diameter:	2.4 meters

5 Parameters of the balancing bunker.

inspection, and comprehensive measurements followed by grit cleaning and disassembly with further non-destructive testing (NDT). This allows us to determine exactly the repairs we will recommend to the client. Each inspection and test report provides details of the scope of work for any proposed repair, which may extend to remanufacturing of the rotor shaft or compressor disks. Extensive machining capabilities and state-of-the-art five-axis CNC mills enable the experienced engineers at Sulzer to create new components, including complex turbine blade designs."

In cases where the rotor has suffered a shaft failure at one end, it may be necessary to replace the end section of the rotor shaft with a shaft stub. Fixing the stub interface to the shaft is extremely demanding. At Sulzer, a PhD-level materials engineer manages the material selection and welding process. In some cases where original components, such as impellers, are damaged, it is necessary to create new parts. If no original drawings exist, Sulzer engineers can still manufacture new components through reverse engineering.

Sulzer engineers use finite element analysis as part of the design process to ensure the mechanical integrity of the impeller design. After manufacturing, the new impeller passes harmonic impact testing to validate the design. Once the engineers have refurbished or remanufactured the components, they then progressively restack and balance the rotor at each stage. After the entire rotor assembly is complete, it is ready for a rigorous quality control inspection. One of the last steps is to carry out an at-speed balance test, the parameters of which are normally agreed on with the client prior to testing. For projects that involve large components, such as the steam turbines from the plant in Colombia, the balancing process requires a large and specialized balancing bunker. The Sulzer balance bunker in Houston is equipped with advanced electronics and diagnostics to provide state-of-the-art analysis capabilities (Fig. 4).

Add-on project ordered

Sulzer handed the complete compressor deck back to the satisfied customer on time. After the original project was completed, the plant engineers requested some additional assistance with the commissioning and startup of the compressor deck. Sulzer sent the field service team back to the plant. The experience and expertise of the team enabled the plant to complete the commissioning phase and get the plant back into normal production after the overhaul.

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6 Removal of the compressor rotor on site.

Shell Buys Award-Winning Subsea Pump Technology

Sulzer and FMC Technologies have received a subsea multiphase boosting pump contract to upgrade one of the pumping modules in Shell's Parque das Conchas, a deepwater oil field off the coast of Brazil. The pump modifications suit the specifics of the oil field with a high shut-in pressure of 517 bar (7 500 psi). They meet Shell's maintenance and service needs with high reliability and short turnaround intervention.

The Parque das Conchas, also known as the Shell BC-10 field, is situated in deep water, approximately 120 km (75 miles) southeast of the Brazilian coastal city of Vitória. The BC-10 asset has water depths ranging from 1 500 to 2 000 meters. It is operated by Shell, with a 50% working interest. ONGC Videsh and Qatar Petroleum International are joint venture partners with 27% and 23%, respectively.

A key part of the success of the project has been the collaboration between Shell, FMC Technologies, and Sulzer. The subsea pump will be manufactured from a global supply chain with a large amount of assembly and testing conducted at Sulzer's facilities in the United Kingdom. The advantage of the mudline pump is that it fits into an existing infrastructure with minor and cost-efficient modifications, yet is smaller and lighter than the pump it replaces. Smaller does not mean lower performance: The pump achieves the necessary oil volume and boosting outputs.

The subsea pump for Shell is based on the Sulzer proven and tested design.

This first subsea pump for Shell from Sulzer and FMC Technologies will be launched in the field in 2017. It will demonstrate the pump's capability to maintain yield levels and achieve excellent reliability targets in the harsh deep-sea environments.

Pumps for the Next-Generation Bioproduct Mill in Finland

Sulzer has been granted an order for the delivery of an extensive process pump package to Metsä Group's next-generation bioproduct mill in Äänekoski, Finland. The construction work on the mill is scheduled to be completed during the third quarter of 2017.

Metsä Fibre, part of Metsä Group, is building a new bioproduct mill in Äänekoski, Finland. This investment of Euro 1.2 billion is the largest ever in the forest industry in Finland. The mill's annual pulp production will be 1.3 million tons, of which 800 000 tons will be softwood pulp and 500 000 tons hardwood pulp. Besides pulp, the mill will produce a broad range of bioproducts, such as tall oil, turpentine, lignin products, bioelectricity, and wood fuel. Sulzer will deliver highly efficient AHLSTAR process pumps, the latest generation of Sulzer MCE medium-consistency pumps, as well as agitators and vacuum pumps. The equipment is designed for high reliability and energy efficiency as well as for low operating costs. The contract includes the manufacturing, testing, packaging, and installation inspection of the equipment. The bioproduct mill will not use any fossil fuels and follow the highest levels of energy, material and environmental efficiency in the world. Sulzer has substantial expertise in providing energy-efficient solutions and also systematically aims to reduce its own environmental footprint.

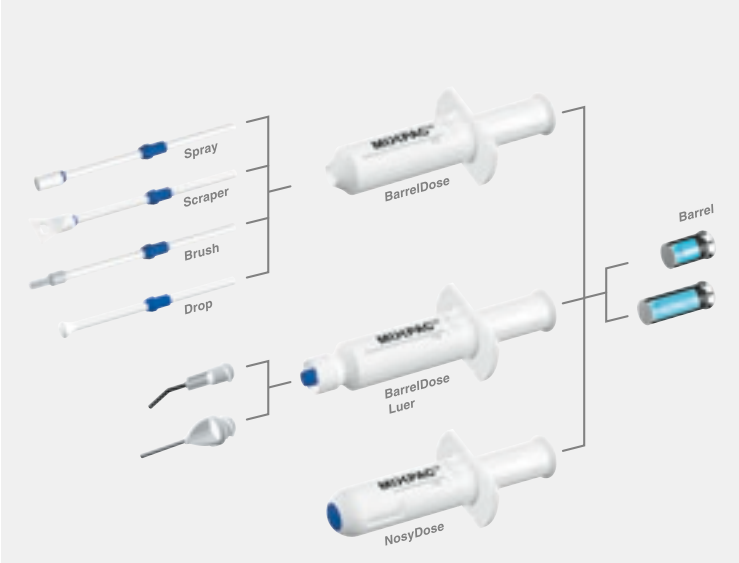
Future bioproduct mill in Finland.

Sulzer Mixpac Barrel System Wins CPhI Pharma Award

In Madrid, Sulzer Mixpac won the global CPhI Pharma Award 2015 in the category "Innovation in Packaging" for its modular MIXPAC™ Barrel packaging and application system. This is a new one- and two-component packaging system for dispensing liquid substances. Daniel Strasser, Global Market Manager Healthcare at Sulzer Mixpac, summarized the jury's decision as follows: "The MIXPAC Barrel System is setting new standards in user convenience, handling ability, multi-optional use, costs, and independency in logistics."

There are two key components: a prefilled polymer barrel and a family of compatible applicator systems. The container, called "Barrel," which is available in packaging sizes from 0.2 to 5 ml, is made of nearly glass-equivalent COC materials. It offers optimal barrier properties, exceptional flexibility, and safety in application, and it protects the sensitive liquid contents.

"After our primary packaging is filled, it is sealed with a multilayer film. It achieves outstanding ratings for vapor and oxygen impermeability, and it is much more durable," explains Josef Ettlin, Head Strategic Innovation at Sulzer Mixpac. "The intelligent and ergonomically proven applicator systems ensure simple and very efficient dispensing of its contents. The MIXPAC Barrel System, which is used for human and veterinary pharmaceutical as well as medical applications, is setting new milestones in userfriendliness. Healthcare professionals can concentrate fully on patient care because the Barrel packaging and application system simplifies the medication process significantly."



The modular concept of the MIXPAC™ Barrel System enables optimal adaptation to the intended use.

Events

July 26 – 29, 2016	HydroVision International 2016	Minneapolis, MN, USA	www.hydroevent.com
August 16 – 18, 2016	Fenasan	São Paulo, Brazil	www.fenasan.com.br
August 24 – 26, 2016	19th China International Adhesives & Sealants Exhibition	Guangzhou, China	http://en.chinaadhesive2000.com
August 29 – Sept. 01, 2016	ONS Stavanger	Stavanger, Norway	www.ons.no/2016
September 12 – 15, 2016	45th Turbomachinery & 32nd Pump Symposia	Houston, TX, USA	http://pumpturbo.tamu.edu
September 20 – 22, 2016	Power-Gen Asia	Seoul, South Korea	www.asiapowerweek.com/en
September 20 – 23, 2016	Innotrans 2016	Berlin, Germany	www.innotrans.de
September 24 – 28, 2016	WEFTEC	New Orleans, LA, USA	www.weftec.org
September 25 – 28, 2016	China Dental Show CDS	Shanghai, China	www.chinadentalshow.com/en/index.htm
September 27 – 29, 2016	Water and Wastewater Fair	Jönköping, Sweden	www.elmia.se/va-massan
October 12 – 14, 2016	MIAC	Lucca, Italy	www.miac.info/en
October 19 – 26, 2016	K 2016	Düsseldorf, Germany	www.k-online.de
October 24 – 27, 2016	Rio Oil & Gas 2016	Rio de Janeiro, Brazil	www.riooilgas.com.br/en
October 25 – 28, 2016	Pap-For	St. Petersburg, Russia	www.papfor.com/en
October 25 – 27, 2016	ABTCP 2016	São Paulo, Brazil	http://abtcp2016.org.br
November 2 – 3, 2016	Advanced Engineering 2016	Birmingham, UK	www.advancedengineeringuk.com
November 14 – 17, 2016	Medica/Compamed	Düsseldorf, Germany	www.medica.de
Additional events online at www.sulzer.com/en/Resources/Events			

About Sulzer

Sulzer specializes in pumping solutions, rotating equipment maintenance and services, and separation, reaction, and mixing technology. We create reliable and sustainable solutions for our key markets: oil and gas, power, and water.
Combining engineering and application expertise, our innovative products and services add value and strengthen the competitive position of our customers. Sulzer serves clients around the world through a network of over 170 locations in more than 40 countries.

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Pumps Equipment

We offer a wide range of pumping solutions and related equipment. Customers benefit from extensive research and development in fluid dynamics, process-oriented products, and reliable services. Our global manufacturing and support network ensures high customer proximity.

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