Innovation through testing—test facilities that support product development

# Proven quality

**Continuous innovation requires state-of-the-art tools and equipment. Though numerical flow simulation (computational fluid dynamics, CFD) has evolved tremendously over recent years, it is the correct correlation of CFD prediction and real fluid testing that enables the development of pumps that fulfill the most stringent needs of clients and industry. Sulzer Pumps therefore operates test beds for both product development and final design validation.**

Sulzer Pumps delivers pumps for demanding applications and, at the same time, continuously improves the technology in order to be able to meet tomorrow's customer challenges. According to the testing requirements of these two tasks, Sulzer runs test beds all over the world—each dedicated to the needs of specific products and markets. Among these are the world's largest installations for full pump string testing at Leeds (UK)—with an installed drive power of 30 MW—and the recently opened largest Sulzer Pumps factory in Suzhou (China) with a test bed featuring eight stations and a total power supply of 15 MW. Key to the success of Sulzer is its capability to fully test every pump prior to shipping to ensure performance and problem-free commissioning.

### Adapted test installation

In Sulzer's competence center for process pumps in Kotka (Finland), the test loop is set up to allow the rapid testing of end suction pumps of all sizes for the pulp and paper, food, metal, and fertilizer industries, as well as desalination processes. The relatively high production volume of the process pump range requires adapted installations. In order to deliver thousands of pumps per

1 Kotka (Finland) research center.

year, the test setup needs to be standardized with a high turnover. The required rapid setup and breakdown is achieved with modular pump interface piping that can be quickly rotated into position using custom-built rotating assemblies holding the required range of suction and discharge pipe sizes.

At the factories there are test beds for each pump type with multiple test beds for different sizes. Apart from a general test station for vertical pumps, process pumps, and multistage pumps with power up to 500 kW, the newest and largest operation test bed of Sulzer Process Pumps is the test station for large process pumps. In this test bed, measurements can be carried out with high flow together with low pressure on the suction side. Such tests with pressures close to the vapor pressure in the suction pipe in combination with high flow rates are very important in the design phase of high specific speed pumps. One use of this low-pressure test rig is the simulation of pumping conditions in large evaporators.

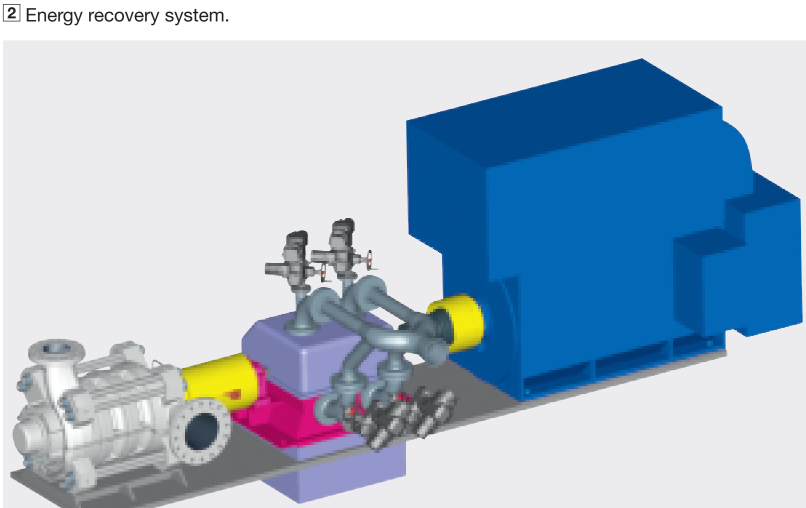
## Energy efficiency

Very similar test beds are available in the product development test bed in the Kotka research center 1. The medium-consistency pulp pump loop—with power up to 600 kW, flow rates up to 1200 l/s, and pressures up to 25 bar—conforms to the requirements of the pulp and paper industry. In this loop, the usual test materials are multiphase suspensions with gas, most commonly a mixture of water, pulp fibers, and air.

To optimize the energy efficiency of the tests, equipment for energy recovery will be installed in the multistage pump loop in Finland 2. A Pelton turbine connected to the same shaft train as motor and pump will recover the high pressure created by the pump. This setup will allow testing of multistage pumps at 2.7 MW power while taking only 1.4 MW from the grid. At optimum conditions, only one quarter of the pump energy is taken from the grid. At the same time, the turbine reduces pressure with high efficiency and with much lower noise emission than when dissipating—and thus losing—the energy in the valves.

The hydraulics group in Finland has optimized both the energy efficiency of the new multistage pump for reverse osmosis and of the associated test bed. This test bed will be used to validate the hydraulic and mechanical improvements to the existing multistage pump range and to develop new pump sizes. Needle valves with electric actuators control the turbine of the energy recovery system, which means the test loop operator using a Pelton turbine will see no difference in the loop operating philosophy. A test series for a pump with a drive power requirement of 1.4 MW will be carried out with just 400 kW of loss.

2 Energy recovery system.



3 With seven singular test loops, the test bed in Oberwinterthur is highly flexible.

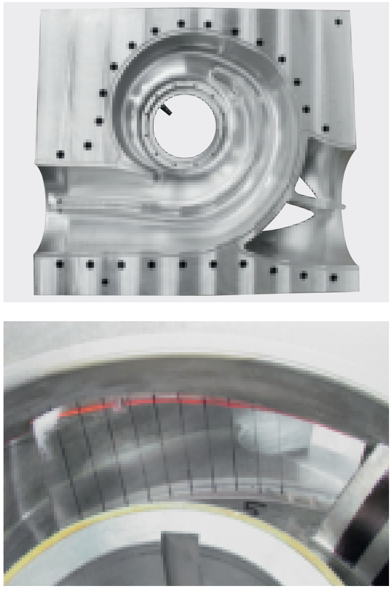
Comparisons with a traditional test setup shows that the test rig will save 8000 kWh of electric power in a single day. As a usual test series for one pump hydraulic takes about 20 days, with the new energy saving test rig, the environmental benefits and cost savings are significant.

## Testing before delivery

In addition to aiding the development of new products, testing also ensures the quality of the output. All pumps leaving the production plant of Sulzer in Leeds are fully tested to both international standards and customer-specific requirements. On this test bed, highly engineered pumps and packages (including the contract driver) for the upstream oil and gas industry are tested before delivery to site.

This enormous facility is equipped with the required systems to test pumps driven by gas turbines of up to 30 MW, large diesel engines, and high-voltage electric motors. Recent modifications to the power grid gave Sulzer in the UK access to 45 MW of electrical power and two in-house variable-speed drives (VSD). The test bed provides sufficient space to install multiple skids, including pump and driver, and, if required, the contract VSD plus all of the support equipment, such as mechanical seal and lubrication systems.

[4] Rapid prototyping using NC machining speeds up the manufacturing of the test components.



This ability to rapidly test large amounts of equipment shows the facility's testing flexibility and highlights the knowledge base available at Sulzer Pumps. These tests ensure that all systems are working in synergy before their arrival on site, thus removing potential delays to the site's commissioning program.

## Testing validates CFD design

In Oberwinterthur (Switzerland), Sulzer Pumps operates a dedicated test bed, which supports product development, large contract-related development projects, and fundamental research [3].

[5] String test of a gas-turbine-driven pump at Sulzer facility in Leeds, UK.

This development test bed is part of the development process for new products or pump ranges as well as of special large engineered pumps. The hydraulics group in Switzerland has significantly contributed to the design of new pump ranges with a greenfield approach. For example, the model testing in Winterthur verified the CFD analysis and hydraulic design of pumps developed for a new pipeline in Eastern Asia.

The main goal of the development test bed is the validation of all characteristics of a newly developed hydraulic before it is used in a new pump design. For this purpose, the validation tests are executed on scaled model pumps produced in aluminum using rapid prototyping (mainly NC machining) [4]. The test bed features seven small-to-medium size loops that are designed to allow high flexibility in terms of the type of pumps that can be tested—with one loop devoted to two-phase testing for the development of the Sulzer multiphase pumps.

During these development tests, all standard pump characteristics, such as flow, head, power, efficiency, and net positive suction head (NPSH) are recorded. NPSH is an important value relating to cavitation behavior of the pumps; it describes the difference between the actual pressure of a liquid and its vapor pressure at a given temperature. Additionally, all relevant information is measured that may be needed for the final design of a pump or in order to ensure its proper behavior under site conditions. These additional tests include:

- internal pressure measurements in order to identify the losses in the different hydraulic components
- radial- and axial-static and -dynamic load measurements
- pressure pulsation measurement at suction and discharge
- visualization of cavitation bubbles on the suction side and occasionally on the pressure side of the vanes
- measurement of pressures, vibrations, or stresses in the rotating parts of the pump, i.e., within the impellers in very special cases

## Research on the impact of surface roughness

For the development of high-performance pumps, both advanced CFD and high-accuracy measurement are needed; these involve specialized tools and highly trained personnel. Sulzer Pumps has invested heavily into both to ensure continuing success and has used the test results to validate CFD data for many years. Due to these efforts, the Sulzer experts know the application limits of CFD for the design of pump hydraulics. Within these limits, design correlations linking CFD results and geometric design parameters give essential support during the design of new hydraulic contours.

Modern research requires the interaction of measurements and CFD calculations in order to improve the accuracy of the design process. Currently, Sulzer specialists are particularly engaged in examining the use of CFD calculations in predicting the influence of surface roughness on pump performance. In order to calibrate the various models for surface roughness in the CFD codes, the developers need surface quality measurements of the pump parts, measurements of their hydraulic performance, and CFD calculations, including manufacturing-quality models.

In the Finnish R&D location, an extensive test program for new multistage pump hydraulics and mechanics will start in 2011. For this pump, every wetted surface has been calculated by CFD. Consequently, expected hydraulic performance, leakage losses, and force balancing are based on CFD calculations. During these tests, the Sulzer engineers expect to gain more in-depth knowledge about the validity of the applied CFD surface roughness model.

## Visualization of cavitation

For projects with demanding suction performance or where high-suction energy leads to a high risk of erosion due to cavitation, Sulzer performs bubble tests on the test rig in Oberwinterthur. These bubble tests are used to assess the extent of cavitation development as a function of suction pressure or NPSH. For this purpose, model pumps are equipped with large windows allowing visual access to the entire eye of the suction impeller over 360°. Sulzer Pumps uses the high competencies of Sulzer Innotec in complex NC machining for the production of these model pumps. These skills are needed to successfully machine the complex 3D contours of casings and impellers out of solid blocks of aluminum.

The window at the suction side allows the experimental confirmation of the suction pressure at which the first bubbles are visible on the vane surface at all positions of the impeller within the pump inlet casing. It also allows the identification of the cavitation length for a given suction pressure and, consequently, the estimation of the according risk of erosion.

Because the pressure side of the vane is not visible in the impeller eye if fully metallic vanes are used, in order to also confirm the cavitation development on the pressure side of the vanes, one or two vanes of the development impellers are machined from acrylic glass. The estimation of cavitation is especially important for large injection pumps for the petroleum industry or for large boiler feed pumps for thermal power plants for which the suction energy and the risk of cavitation erosion may be very high.

**Focus on prototype performance**

When a model pump is used in the development of new suction impellers for these applications, it is designed at prototype scale. This procedure allows the job impellers to be tested in order to confirm cavitation-free operation on site. Because of the presence of a window that limits the suction pressure, as a compromise, tests are performed at a reduced speed compared with site conditions, and the full-speed performance is calculated using standard affinity laws.

The development test bed is also used to check the mechanical performance of key elements of pumps, such as bearings or seals. For example, dedicated testing equipment has been developed in order to test different material combinations for the product-lubricated line shaft bearings under real site conditions using water charged with sand.

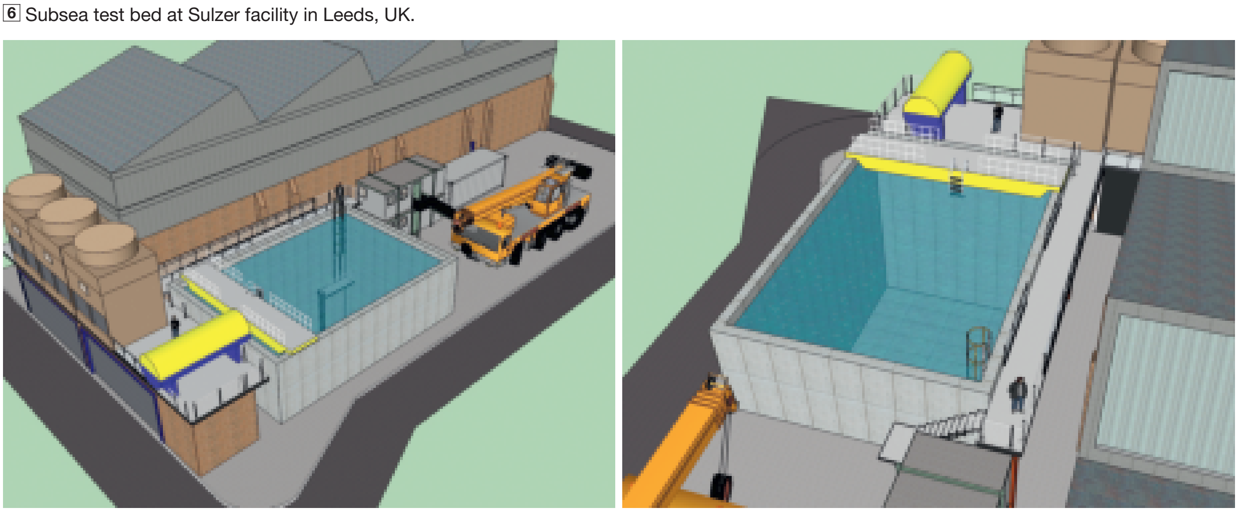
**Prepared for future demands**

Sulzer Pumps continuously develops and improves the testing methods for new products and for machines. For example, the demand for subsea pumping is growing, along with the requirements that pumps operating under water have to fulfill. To be able to test subsea processing equipment under realistic conditions, Sulzer is investing in a dedicated multiphase subsea test bed in the UK. This state-of-the-art addition to the already impressive string testing facilities in Leeds 5 will position Sulzer as the market leader with respect to pump-testing facilities. In this installation, it will be possible to examine subsea pump/motor packages with weights approaching 100 tons in water depths of up to 10 m 6.

When deployed in the open ocean, these pumps will operate in many kilometers of water depth and are designed to take high external and internal pressures whilst delivering the high pressure rises that customers require. The first pump that will be tested once the test bed is commissioned will be a 3 MW, 6000 rpm multiphase pump able to deliver over 100 bar pressure rise—well suited for many of the current subsea applications.

Current specifications and market ideas set the standards for capabilities and capacity of any new test bed. Sulzer, however, follows the motto "designing for the future" and requires that new test installations must consider future possibilities for expansion. Sulzer thereby plans to keep these investments operational and useful for many years, as both products and markets mature and adapt. This philosophy makes it possible for Sulzer Pumps to deliver pumps adapted to market and client requirements now and in future years.

6 Subsea test bed at Sulzer facility in Leeds, UK.



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