

Sulzer Pumps delivers pipeline pumps with interchangeable hydraulics, enabling possible flexible operation

# Two pumps in one casing

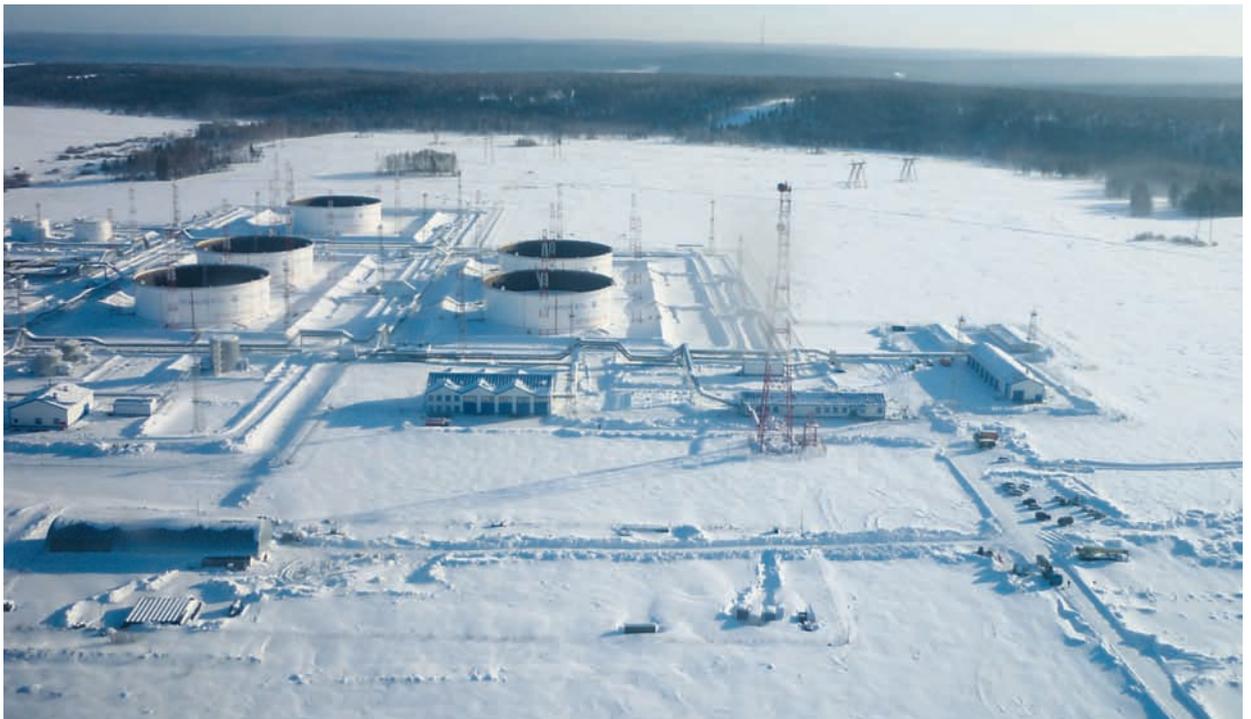
Russia is currently building a pipeline system almost 5000 km long, that connects oil fields in Siberia with markets farther east, e.g., China and Japan. Because this pipeline system is being built in two stages, the operating conditions for the pumps installed in the initial phase will change as pipeline length and required flow increase for the final phase. Sulzer Pumps developed pumps with interchangeable hydraulics in one casing, a feature that allows changing the pump characteristics according to the stage of pipeline construction.

Russia is keen to develop more outlets for its massive reserves of crude oil. The gateway to the east for Russian oil will be the eastern Siberia Pacific Ocean (ESPO) oil pipeline, a 4700 km (2900 mile) pipeline system operated by Transneft, a Russian state-owned company responsible for the national oil pipelines [1]. With a total network length of almost 50000 km, Transneft owns the world's largest

pipeline system. Once fully constructed, ESPO will transport crude oil from fields in eastern Siberia and the Khanty-Mansi Autonomous Okrug in western Siberia to the Asian Pacific markets of Japan, China, and Korea [2].

ESPO's first stage comprises the construction of a 2757 km (1713 mile) section with a capacity of 30 million tons (220.5 million barrels) of oil per year. One oil barrel equals 42 US gallons or 159 liters.

The first part of the pipeline, with a diameter of 1.22 m, links Tayshet in east Siberia's Irkutsk region to Skovorodino in the Amur region, in Russia's far east. There will also be a branch from Skovorodino to Daqing in China, with a planned capacity of 30 million tons a year. The second stretch will run an additional 2100 km (1304 mile) to the east from Skovorodino to the Pacific Ocean terminal at Kozmino. This terminal can



[1] In the harsh and remote Siberian environment it is important that the installed pumps are efficient, reliable, and require a minimum of maintenance.



2 Government-proposed far east oil and gas pipelines

serve tankers with deadweights from 80000t to 150000t and will eventually have three loading booms. The second leg of ESPO will pump 367.5 million barrels of oil annually, whereas the capacity of the stretch from Tayshet to Skovorodino will finally be raised to an annual 588 million barrels.

Along the route, 32 pumping stations will move the fluid, including 13 stations with a total tank-farm storage capacity of 2.67 million cubic meters (94310000 ft<sup>3</sup>). Each pumping station will comprise three pumps in series and one spare pump. In the first phase, six pumping stations are required to move the oil eastwards.

The first phase also includes the construction of an export terminal and of a dedicated 35MW power station in Olyokminsk. In this power station, five generating sets with crude-oil-fired engines will deliver the electricity to power the remote pumping stations.

In November 2006, Sulzer Pumps received the order from Russia to design and build the pumps for the first phase of this exceptional project. The order includes main pipeline pumps as well as vertical-booster and vertical-loading pumps.

### Flexible operation possible

In the initial phase, the pipeline is shorter, and fewer production systems are hooked up to the system. The length of the pipeline influences the pressure losses

and thus the required head to be delivered by the pumps. As more oil fields are connected to the system, the required flow rate increases compared with the initial configuration 3. The parameters head, discharge flow, and rotating speed determine the specific speed of a pump and thus influence the shape of the impeller.

Specific speed is a characteristic number for each pump hydraulic and it increases with higher flow and lower head. For the ESPO pumps, the changing head and flow rate made it impossible to cover all requirements with a single pump. In the initial phase, a pump with lower specific speed is required, whereas, in the final phase, the necessary specific speed is higher. In order to keep the investment as low as possible and to facilitate flexible operation of the pipeline, the engineers of Sulzer Pumps designed two hydraulic configurations consisting of one impeller / diffuser set for the initial phase and one impeller for the final phase that fit into the same pump casing.

For the first construction phase of ESPO, the flow and head requirements are considerably lower than for the final phase. The first phase hydraulic has a smaller impeller diameter but approximately the same shaft diameter as the final flow hydraulic. The diffuser for phase one accommodates the lower flow rate and fits into the volute type pump casing that is matched to the phase two

Phase 1	
Discharge Flow	4500 m <sup>3</sup> /h 159 000 ft <sup>3</sup> /h
Variable speed	1542–2910 min <sup>-1</sup>
Power consumption	4.6 MW
Phase 2	
Discharge Flow	9600–12 000 m <sup>3</sup> /h 340 000–424 000 ft <sup>3</sup> /h
Maximum differential head	375 m (1230 ft) at minimum flow (9600 m <sup>3</sup> /h; 340 000 ft <sup>3</sup> /h)
Variable speed	1465–2695 min <sup>-1</sup>
Power	13 MW, driver rating 14.5 MW
Design Pressure	105 bar (1523 psi)
Hydrotest Pressure	150 bar (2176 psi)

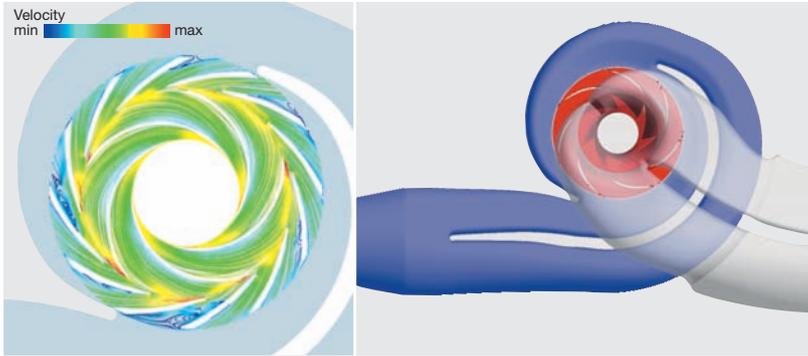
3 Main design data of the pumps for the 2 phases of ESPO.

hydraulics. Once all oil fields are hooked up, the flow rate increases such that it is too high for the initial low flow-hydraulic. At this stage, Sulzer will install the high-flow impeller.

The volute casing is hydraulically designed such that it matches the performance of the high-flow impeller.

### Design for maximum load

With higher flow rate and head, the required power input increases. This higher power means that shaft, bearings, and casing have to handle higher loads in the final expansion stage. The Sulzer specialists designed all mechanical parts so that they can take the increased load when the pipeline operates at full length and full capacity. Thanks to this approach, no change is required to the pump casing, shaft seal, or bearing assembly when changing the hydraulics



4 CFD supported the pump design. The diffuser inserts guide the flow in the volute, designed for flow rate which will be almost tripled in phase 2.

for the higher discharge. Also, the shaft remains the same for both hydraulic designs. Equally, the whole drive system is designed for the full-load case.

These features make the ESPO pumps like two pumps in one casing, both working around the best efficiency point in their specific operating range. In addition to the hydraulic adjustments, a variable-speed drive further increases operational flexibility.

The experts at Sulzer Pumps had to develop a pump that could operate at optimum efficiency with flow rates of 4500 and 12000 m<sup>3</sup>/h. Such a demanding design task required the use of the most modern tools in Sulzer's R&D department in Winterthur (Switzerland). Computational fluid dynamics (CFD)4 made it possible to predict the interaction between rotor and stator for the low-flow and the high-flow operating condition.

The flow field analysis of the full stage gave the designers valuable insight and helped to optimize rotor/stator interaction to achieve maximum efficiency and low-pressure pulsations for the wide range of given operating conditions.

#### Stringent mechanical analysis

Today, the design of a pump is an integrated process including hydraulic development and structural analysis. Before a hydraulic contour is released for model or prototype manufacturing, it also has to pass stringent mechanical analysis with the most advanced tools using the finite element method (FEM) 5.

The mechanical design department carried out a complete 3D calculation of the pump casing, including bolts, nuts, and gasket for the most critical load cases. The hydrotest pressure of 150 bar was checked as well as the risk of interstage leakage and the deformations and stresses in the casing.

#### Fine-tuning on the test rig

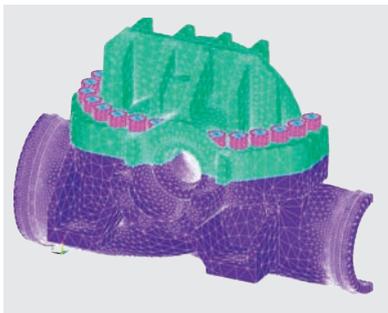
In order to verify the CFD based impeller design, Sulzer carried out model tests in the Winterthur laboratory 6. Scaled-down models of the hydraulics for phase one and phase two were machined from aluminum blocks using a high-precision five-axis milling machine. The measurements confirmed the CFD predictions for the hydraulic configurations with the lower specific speed for phase one, whereas the design for the second phase needed some fine tuning on the test rig. In addition to the model test, Sulzer

Pumps carried out string tests with the pumps in the Leeds (UK) workshop, which was also responsible for pump manufacturing. For the tests of the designs in both the initial and the final phases Sulzer built a special test bed in Leeds. This new installation made it possible to execute out tests across the full operating ranges and at the maximum power of 14.5 MW. 24 string tests were carried out over a period of ten months to prove the complete integrity of the skidded units.

6 Precisely machined model pumps at a reduced scale enable the designers to fine-tune the hydraulic design on the development test rig.



5 Structural analysis of the casing for the most critical load cases ensures mechanical integrity of the full operational life of the pumps.





7 Pumping station of the ESPO pipeline with Sulzer pumps in operation.

### Service contract to ensure reliable operation

The ESPO pipeline is in the focus of the Russian government, because it connects the west Siberian Oil fields with China 7. Russian Prime Minister Vladimir Putin inaugurated the ESPO oil pipeline during a ceremony at the Kozmino oil terminal on December 28, 2009, calling it a “strategic project”. Therefore, its safe and reliable operation is of high importance. To ensure best-quality maintenance to minimize unexpected outages, a service contract was signed in December 2009. In the scope of this service contract, two teams of Sulzer service engineers supervise the technical maintenance performed by the person-

nel of the customer on the Sulzer pumps. Vostoknefteprovod Limited Liability Company, the operating company of the ESPO pipeline is a subsidiary of Transneft. The Sulzer teams are based in the customer’s service centers in Bratsk and Neryungri, east Siberia, and sequentially visit each of the pumping stations. In these pumping stations, the main pipeline pumps and additional booster pumps, all manufactured by Sulzer Pumps UK, work around the clock.

The oil deliveries by the pipeline started in early 2010 and the first cargo of oil was delivered to Japan’s Mitsubishi through ESPO on January 30, 2010, according to the Russian oil producer Gazprom Neft.

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