



The World's Largest Injection Pumps

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At the end of November 2001, the Azerbaijan International Oil Company (AIOC) awarded contracts for the injection pumps for its Azeri-Chirag-Guneshli Full Field Development (ACG-FFD) programme. Along with the associated Baku-Tbilisi-Ceyhan (BTC) pipeline, these projects are probably the world's largest oil and gas developments today. AIOC invited three potential pump vendors to bid for the pump design and – after extensive evaluation – selected Sulzer Pumps Ltd. to manufacture, package and string-test these significant pump packages.

▶ The ACG field lies offshore Azerbaijan in the Caspian Sea (Fig. 1). It has proven oil reserves of 5.4 billion barrels and 100 billion m³ of associated natural gas (1 billion = 10⁹), representing roughly half of the proven oil reserves in Azerbaijan's offshore fields. Fundamental to the development

are four massive water injection pumps, each rated at 27 MW, which will have the combined capability to inject up to 1.0 million barrels of sea water per day into the reservoirs at a pressure of 480 bar (Fig. 2). The pumps, which are driven by Rolls-Royce RB211 gas turbines, are 50% greater in

power than any other sea water injection pump ever built.

Direct Drive Reduces Lube Oil Requirement

The pump design was selected taking the following into account:

- ▶ The gas turbine output speed is set at 4800 rpm, so a direct-driven pump was selected to avoid the use of a gearbox. This solution saves overall package space, cost and significantly reduces the lube oil flow requirements.
- ▶ Sulzer-internal impeller erosion tests showed a head-per-stage limit of 600m. Therefore, the flow velocities through the impellers should be kept to below 55 m/s to have marginal erosion taking place with duplex metallurgy.

BTC Pipeline

The Baku–Tbilisi–Ceyhan pipeline is predominately 42" (107 cm) in diameter, with eight pump stations and 98 valve stations. The pipeline will cross more than 150 rivers and will climb to a high point of 2700m before returning to sea level at Ceyhan on the Mediterranean Sea. The construction work commenced first quarter 2003 and will be completed by the end of 2004, ready to export first oil from the ACG Azeri Development planned for the first quarter 2005.

Sulzer Pumps has received a significant order to provide both motor-driven and turbine pump packages for this important pipeline.



1 The Chirag platform operates in 120m deep waters in the Caspian Sea, approximately 100 km east of Baku. Sulzer pumps support the development of Azerbaijan's rich oil and gas reserves.

Two hydraulic designs – specific speed $n_q=27$ (1400 US units) and $n_q=18$ (930 US units) – were selected to meet the demanding injection profile, nominally 427–5958 m³/h at 4664m head (rated flow of high-flow cartridges 1650 m³/h). Both designs are 8-stage in-line designs, incorporating a balance drum to reduce the residual axial thrust (Fig. 3). Both hydraulic selections were modified from existing and proven designs. The pump cartridge was also designed, so that the $n_q=18$ impellers and diffusers could be fitted into the high-flow cartridge design, utilising the same shaft and bearings without modification.

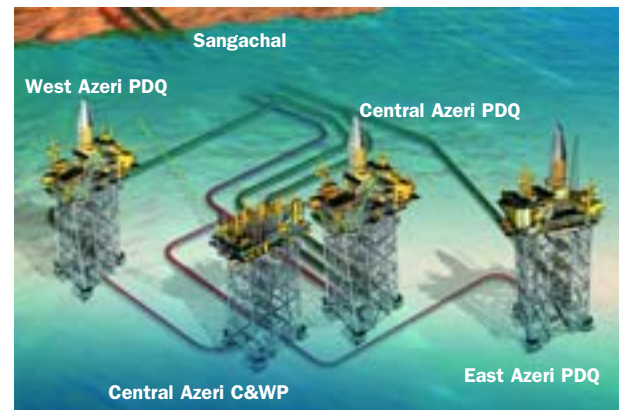
Continuous Over-Load Operation Possible

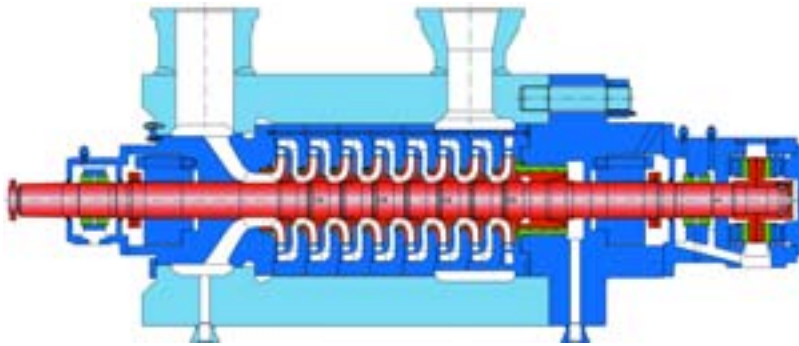
During the winter months, the injection rate will be increased by operating the turbine at 105% over speed. The pump has therefore been designed to operate continu-

ously at this rating. At the rated head of 4664m, the pump can deliver a flow of 2020 m³/h, an increase of some 20% over the rated flow.

Owing to the high absorbed power of these pumps, the shaft diameter had to be increased beyond the size required for the reference hydraulics. Larger shaft sizes result in decreasing the eye area of the impeller and hence pump performance. In order to ensure reli-

2 The 27-MW injection pumps delivered by Sulzer Pumps will operate on the unmanned C&WP platform.





3 Design of the world's largest-power injection pump (27 MW). The rated impeller diameter is 420 mm, the maximum diameter of the barrel casing is 1250 mm, and the total pump weight is 19,800 kg.

able hydraulic performance, exact scale models of both designs were manufactured using rapid prototype techniques and tested in a three-stage test pump. This work was undertaken by Sulzer Pumps in Winterthur, Switzerland, and witnessed by the client.

Flexible Operation with “Low-Flow Cartridges”

The salient feature of the project is the variable injection profile. Low-flow injection rates are expected in the first two years of production, followed by fairly constant flow rates for the next ten years and finally some variable flow rates for the remaining life of the field (Fig. 4). Turn-down can be achieved

by operating the injection pump at reduced speeds. However, due to the required low injection rate of only 427 m³/h, this level of turn-down is most economically and easily achieved by means of a “low-flow cartridge”.

High-Quality Manufacturing Process

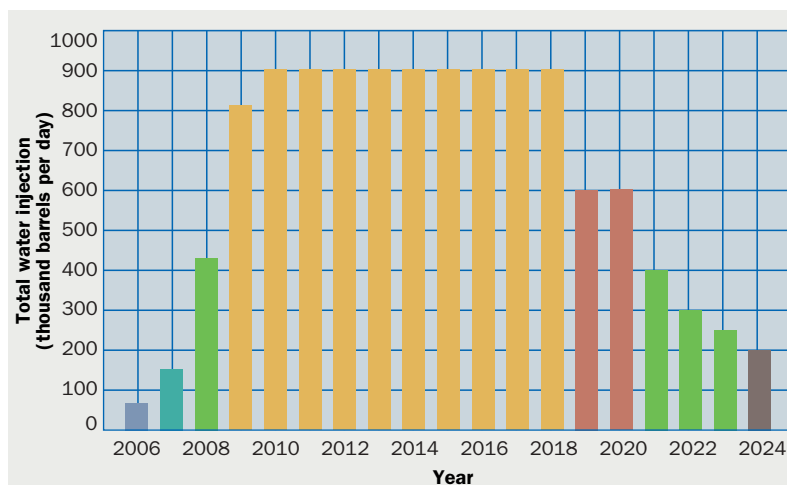
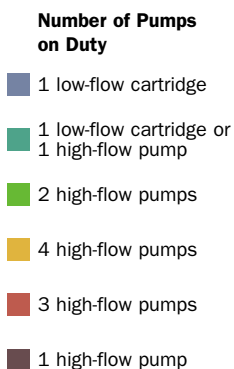
The major challenge in producing such large pumps is in the “manufacturability” simply due to their physical size. In particular, manufacture of the barrel casings and covers in super duplex material is critical.

Super duplex is now the material of choice for the injection pump manufacturer, combining excellent

Power Concentration

The main issue of the injection pumps that concerned the operator BP and its engineering contractor Kellogg Brown & Root was the absorbed power of the machines and hence the physical size. Even though the pumps have a high pressure duty, this aspect became a secondary issue, as Sulzer Pumps had just manufactured and tested the world's highest-pressure seawater injection pump “Thunder Horse” (see STR4/2002, p.10). However, Sulzer Pumps was able to show that it had manufactured injection pumps rated at 18.65 MW and boiler feed pumps at 35 MW for Lippen-dorf power station in Germany.

erosion/corrosion and pitting resistance with high mechanical strength. However, with increasing section thickness comes very significantly increased risk of embrittlement occurring during heat treatment.



4 Total water injection profile required over life of the oil field. Note the flexibility achieved with the provision of a low-flow cartridge in the first year.

Sulzer Pumps worked closely at all stages with its preferred forge master to ensure that the 10,000-kg barrel casings could be manufactured with a high degree of confidence. Four barrels and covers have now been forged and heat-treated successfully. In August 2003, the barrel casings were fully fabricated, awaiting final machining within the Sulzer Leeds works (Fig. 5).

Extensive Testing Proves Performance

Given the criticality of these pumps to the overall success of the project and the physical size of them, the operator has quite understandably called for extensive testing to be carried out on the units prior to shipment:

- ▶ Each pump and all exchange cartridges will be full-speed, full-load performance-tested.
- ▶ Each pump and all exchange cartridges will be full-speed, full-load string-tested with their respective Rolls-Royce RB211 gas turbines on Sulzer's recently completed 30-MW gas turbine test facility (Fig. 6). All contract instrumentation, sequence logic and controls will be functionally proven as part of the test.
- ▶ Mechanical tests on one of each size pump cartridge will be carried out with new and fully worn (2× design) clearances to prove the rotor dynamic predictions made during the design.

During 2003, Sulzer Pumps is manufacturing the world's largest injection pumps. The attention given to the selection, pump design, analytical investigations, focus on being able to manufacture critical components and the full



5 Forged and fully fabricated barrel casings weighing 10,000 kg each.

risk assessment undertaken formed the backbone to the design submission. Orders placed to date with Sulzer Pumps for supply of equipment for the ACG-FFD amounts to over 25 million GBP (40 million USD), and this taken over the last two years. ◀

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6 Sulzer's new 30-MW turbine test facility in Leeds.

