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...
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).

\[
H_L = \sum \left( \frac{f_n}{d_n} + K_n \right) \frac{C_n^2}{2 \cdot g}
\]

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

\[
P_{\text{Motor,ie}} = P_S - 3 \cdot I^2 \cdot \left( R \cdot \cos \phi + X_L \cdot \sin \phi \right) \cdot \cos \phi
\]

- 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.
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.

Author: Fred Robinett
sulzertechnicalreview@sulzer.com