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Major refinery uses reliable fiscal metering system

Reliance Industries Ltd., ranked 99th on the Fortune 500 list of the world's major corporations, operates the largest refinery and petrochemical complex. Located in Jamnagar, Gujarat, India (**FIG. 1**), this refinery processes 1.24 million bpd (MMbpd) of crude oil. Largely due to this facility, Jamnagar has emerged as one of the world's refining hubs.

As shown in **FIG. 2,** this refinery features the world's largest crude distillation, fluid catalytic cracking, delayed coking and paraxylene (PX) units. The complex involves the operation of 50 various processing units to produce PX, ethylene, polyethylene, polypropylene, transportation fuels (diesel, gasoline and aviation fuels), and many other products.

Moving and measuring crude oil. Crude oil arrives at the refinery's all-weather deepsea port, which is capable of receiving all types of oil tankers and vessels. Two 48-in. subsea pipelines carry the crude from the port to the refinery.

Because of various taxes and economic incentives, and the placement of the new refinery in a Special Economic Zone (SEZ), the flow of crude oil and refined products must be closely measured at various points, both in the new SEZ refinery, and in the old refinery, as shown in **FIG. 3.** The value of the products produced at the Reliance refinery is about $20 billion (B) annually. So, fiscal (custody) transfer and allocation measurements are crucial. Fiscal transfer flow measurement errors of 0.2%/yr could cost this refinery $50 million. For this and other reasons, 76 flowmetering systems are installed in various locations throughout the refinery to monitor the flow of incoming crude oil and products within the refinery, and the outgoing of refined products.[1]

Modular units. The refinery complex consists of an existing refinery and a new, connected refinery. Construction of the new $6 B refinery began in 2005, with 75,000 construction workers onsite and 7,500 engineers working at eight global locations. Engineers for the flowmetering systems were staffed at offices in Singapore and Houston, Texas.[1] Construction took only three years, a new benchmark for building a grassroots refinery of this size and complexity.

As details of the refinery processes were being finalized, a contract for the flowmetering systems settled on 76 metering systems with delivery in 12 months. An integrated engineering system process was applied to design the turnkey metering systems. This method used an automated 3D scale model based on the approved P&IDs (**FIG. 4**).[2] The metering systems were constructed as modular units to expedite delivery and minimize installation cost.

The 3D models helped Reliance review the desired measurement solution ahead of time at various stages of the project. The models allowed Reliance engineers to implement changes to the system design with ease. The models also helped Reliance and the main E&C engineers review the complete bill of materials for manufacturing, and perform engineering reviews on the general arrangement, stress analysis, center-of-gravity calculations and compliance to the API MPMS standards.

High-accuracy liquid ultrasonic flowmeters are used on the fiscal metering skids that determine the custody transfer

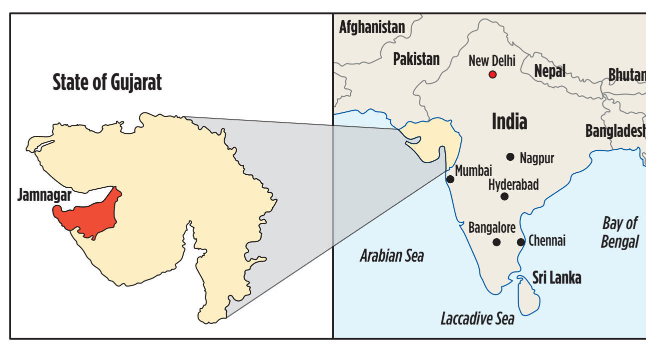

FIG. 1. Reliance Industries, India's largest private company, built the world's largest oil refinery in Jamnagar. Consequently, Jamnagar has been nicknamed the "Oil City of India."

FIG. 2. The Reliance refinery in Jamnagar, India, occupies 1,700 acres and processes 1.24 MMbpd of crude oil.

of all petroleum products, ranging from heavy crude to light hydrocarbons processed for the export market. Each skid included a flow computer, control valves with advanced digital valve controllers, vibrating-type density meters, solenoid valves, and pressure and temperature transmitters. The flow computers allowed fully automated systems. All flow computer measurement data are accessible over the Ethernet network; it provides uplinked system redundancy at multiple levels. Multiple meter runs provide flow measurement hardware redundancy.

Similar metering systems are used to measure allocation transfers between the export refining complex and the existing plant for taxation purposes. These allocation skids measure refinery intermediates, ranging from low-lubricity hydrocarbons to heavy intermediates. The allocation skids include the same basic equipment as the custody transfer skids.

Reliance's Jamnagar refinery uses 76 flowmetering stations to monitor oil and gas products that are valued at $20 billion.

Both the custody transfer and allocation metering systems were assembled at a triple ISO-certified skid-building facility in Singapore (**FIG. 5**) and shipped to the refinery jetty at Jamnagar by bulk marine cargo ship.

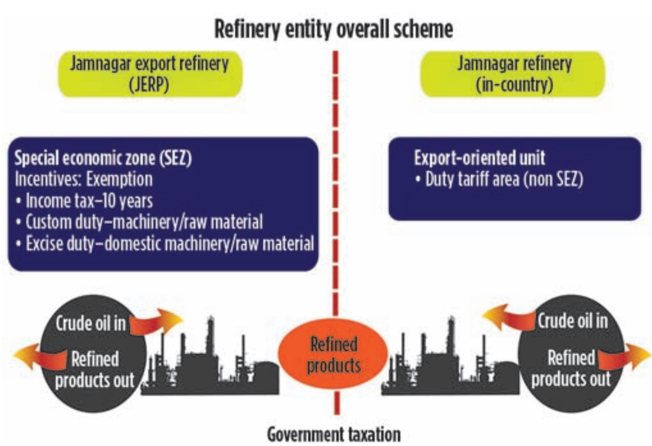

FIG. 3. Because of tax regulations, flow of crude oil and refined products must be monitored at several places in the refinery complex.

FIG. 4. A 3D modeling system was used to concurrently design and build the flowmetering skids.

Proving ultrasonic meters. Ultrasonic flowmeters were selected as the accounting meters because they can handle a wide variety of process fluids including white oil, black oil, 20 types of crude oils, refinery intermediates and end products. These fluids vary in viscosity from 1 cP to 360 cP, and they also vary in temperature.

The complexity of any refinery is defined by its Nelson Complexity Index (CI). This index is a measure of secondary conversion capacity in comparison to the primary distillation capacity. It is also an indicator of not only the investment intensity or cost index of the refinery, but also the value-added potential of a refinery. Adding up the complexity values assigned to each piece of equipment, including crude distillation, determines a refinery's complexity based on the Nelson CI.

The Nelson CI averages 9.5 for US refiners, and 6.5 for European refineries. The Jamnagar facility has a CI of 14, one of the highest in the world. One of the reasons for the high index value is the refinery's ability to process 20 different crudes, plus intermediates and end products.

Because of the wide variety of incoming crude and outgoing products, ultrasonic flowmeters were chosen for the metering stations. To ensure transaction repeatability of 0.05%, master meters and provers were installed on each metering skid, and the skids were provided with mobile or fixed-compact provers. There are five compact provers at the Jamnagar facility.

Proving is done in accordance with API MPMS 4.2, 4.5, 4.8 and 5.8 recommendations. Field proving of master meters is done "in situ," meaning the prover is placed in series

FIG. 5. This fiscal metering skid was assembled in a skid-building facility in Singapore and shipped to the refinery by boat.[1]

with the accounting metering system.

Because the master meter is used to prove the custody transfer or the allocation flowmeters, the master meter has to be proved itself prior to, during or after a transfer, under similar operating conditions. This is called "proving the prover," and it is done with a compact prover. According to API MPMS, the master meter factor shall be based on at least two consecutive proof runs that agree within +/– 0.01%. When used to prove the accounting flowmeters, repeatability must be ±0.05% over five consecutive proving runs.

The old refinery uses ball provers, but compact provers were chosen for the new SEZ refinery. The new provers are essentially the same as a ball prover except it has a smaller volume—about 20 to 30 times smaller—so its pre-run times can be as short as 0.1 seconds. Because the prover volume is small, a series of consecutive prover passes are typically done to constitute a proving run that is equivalent to a ball prover.

Another benefit is the smaller test measure used for water draw than that is required for a conventional ball prover. This creates significant savings in operating expenses and time because a water-draw witness is required during a routine or regulatory test. The compact provers are mobile and can be moved easily from skid to skid, reducing the number of provers needed, and lowering the cost.

In some fiscal or allocation measurement skids where mass measurements are needed, a double-walled vacuum-sphere pycnometer is used for density proving of the vibrating-type density meters. For example, in a propane or butane measurement skid, volume is measured by an ultrasonic flowmeter and density is measured by a densitometer. The pycnometer obtains the density meter factor for the densitometer in situ, and serves as the density prover. Density proving is done in accordance with API MPMS, and is particularly critical because it is one half of the mass proving equation.

Proven results. All key processing units are operating close to, or at, their respective design capacities. The support units and utilities are fully operational, and the refinery has been operating at near 100% capacity with minimal downtime since it began operation in December 2008.

Given the refinery's unprecedented size and scope, high level of processing complexity, the various system design permutations and combinations, and the requirement to equate each option according to cost and value—this was a particularly difficult application for flowmetering. More than 100 ultrasonic flowmeters have proven their ability to measure a wide range of fluids across this refinery, and the fiscal metering skids have met all regulatory requirements. HP

NOTES

[1] The metering systems from Daniel Measurement and Control, a business unit of Emerson Process Management, are installed in various locations around the Jamnagar refinery.

[2] Daniel used its 3D modeling system to concurrently design and build 76 flowmetering skids.

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