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Improvements in Refinery Loss Control

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Introduction

The environmental and financial impact of losses at a refinery are of tremendous importance. In today's operating environment, the refiner must make efforts to understand the extent and source of losses in order to reduce them.

Achieving a high quality mass balance of the refinery is the means by which refinery losses are calculated. Understanding and evaluating the mass balance for the refinery depends on distinguishing between real losses and apparent losses stemming from measurement error. This involves improving the dynamic flow measurements for all mass balance points.

At the YPF Refinery in Luyan DeCuyo, Argentina, refinery losses are treated as a key performance indicator, along with energy consumption and volumetric expansion. Refinery losses are tracked on a monthly basis and have improved dramatically in the last five years, from 5% of the crude charge to 0.6-0.8%. This paper will discuss the refinery mass balance, the largest potential sources of error, and the steps that YPF took to improve the balance and understand the source of its losses.

Refinery mass balance: the importance of measurement

The key to acheiving a reliable refinery balance is proper measurement of each component factoring into the balance.

Loss is defined by the following equation:

Loss = inputs - outputs - current stock + previous stock - fuel

Loss cannot be measured directly. It must be calculated from the measurements of relatively large quantities. All measurements are subject to error, some have fixed biases, and others are random. The objective is to understand the potential errors, identify which measurements have the greatest impact on the balance, and take steps to minimize these errors.

Accurate crude inputs are critical

The fewer measurement points there are in the process, the larger the total uncertainty. The impact of each component on the balance is directly proportional to the component's percentage of the total balance. Therefore, the measurement of crude imported into the refinery is perhaps the most impor-

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tant measurement. Moreover, multiple measurements can result in a significant randomization effect, in which uncertainties cancel each other out. Thus the uncertainty associated with each point becomes less significant.

The degree of uncertainty in crude import measurements depends on whether the refinery is receiving crude from a ship or pipeline. If crude oil is unloaded from a ship into a shore tank, the amount unloaded is typically quantified by performing tank dips and using tank calibration tables. Errors in level measurement can be significant, as can measurement errors in temperature, water content, and density—all of which are necessary to convert volume into mass.

Metering crude oil, instead of using level measurement, is generally the most accurate because fewer sources of error exist. Crude oil transferred via pipeline is commonly metered. New developments in metering technology have made it possible to also meter crude oil being tranferred from a ship. Water content is still a source of error, as can be the density measurement if a volumetric meter is used.

Fuel measurement can be a large, unexpected source of error

Refinery fuel, the fuel consumed within the refining processes, typically only amounts to about 7% of the crude import figure. However, because of the large uncertainty in the measurement of fuel oil and fuel gas, the error contribution to the total balance can be significant.

In many cases, fuel gas and fuel oil are measured using orifice plate/dP technology. However, this technology is prone to measurement error caused by changes in fuel composition—something common to fuel gas and fuel oils burned in refineries. Orifice plate/dP devices must be recalibrated whenever fuel compostition changes, otherwise, overall fuel gas mass measurement uncertainty can be in the +/-5% range. Since recalibration is difficult, costly, and time consuming, users of this technology are often forced to live with innaccurate measurement.

Density measurement required to convert volume to mass

Because refinery balances need to be made on a mass basis, and because measurements are traditionally made using volumetric technology, density measurement accuracy becomes critical. Unfortunately, density measurement accuracy is rarely given the importance it deserves.

Density measurement is sometimes made with an on-line device, but more often by sampling. If sampling is used, measurements must be taken at a location and frequency that ensures a representative sample. Further, the samples must be properly handled and correct laboratory procedures followed. In particular, the problems of light end losses and wet oil need to be properly characterized. Temperature and pressure corrections must also be made because sample conditions may vary from process conditions.

YPF refinery evalutes systems for mass balance improvements

YPF recognized many sources of error in calculating the refinery loss figure. To define actual losses, the refinery had to first reduce apparent losses by improving its measurement systems.

YPF evaluated several options for improving measurement control. Following a thorough analysis, the refinery decided that measuring mass directly, rather than inferring mass from volume and density measurements, was the only option that would consistently provide satisfactory results without creating high maintenance costs.

YPF installed Coriolis flowmeters on all liquid dynamic flow measurement points. Coriolis flowmeters measure mass directly and are virtually unaffected by changes in density or other fluid properties. Although density is not required to measure the mass flow, Coriolis meters simultaneously measure density. Density can be used to determine volumetric flow rate — a process variable that is often of interest to the refiner.

The theory of Coriolis-based direct mass measurement

The Coriolis meter measurement principle is based on Newton's Second Law: Force = mass x acceleration (F=ma). Two flow tubes within the meter are set in motion at their natural frequency by an electomagnetic drive coil mechanism. As fluid flows into the sensor tube, it is forced to take on the vertical momentum of the vibrating tube. When the tube is moving upward during half of its vibration cycle, the fluid flowing into the sensor resists being forced upward by pushing down on the tube. Having the tube's upward momentum as it travels around the tube bend, the fluid flowing out of the sensor resists having its vertical motion decreased by pushing up on the tube. This causes the tube to twist. When the tube is moving downward during the second half of its vibration cycle, it twists in the opposite direction. This twisting characteristic is called the Coriolis effect. This is illustrated in Figure 1.

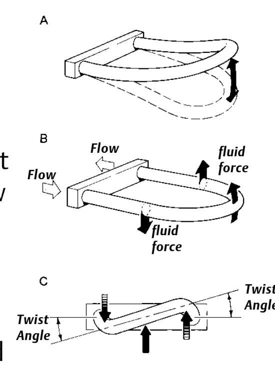


Figure 1. Theory of operation

According to Newton's Second Law of Motion, the amount of sensor tube twist is directly proportional to the mass flow rate of the fluid flowing through the tube. Electromagnetic velocity detectors measure the velocity of the vibrating tube. Mass flow is determined by measuring the time difference exhibited by the velocity detector signals. During zero flow conditions, no tube twist occurs, resulting in zero time difference between the two velocity signals. With flow, a twist occurs, resulting in a time difference between the two velocity signals. This time difference is directly proportional to the mass flow.

The theory of Coriolis-based density measurement

Density measurement using a Coriolis meter is independent from the flow measurement. The flow is proportional to the twist of the tubes, whereas the density is inversely proportional to the frequency of oscillation of the tubes. A Coriolis sensor is vibrated at its resonant frequency using a drive coil and feedback circuit. This resonant frequency of the tube assembly is a function of the geometry, material of construction, and mass of the tube assembly. The tube assembly mass includes the tube and the mass of fluid inside the tube. The mass of the tube is fixed for a given sensor. Since mass of the tube is equal to density x tube volume, and the tube volume is constant, frequency of oscillation is related to fluid density. The density of the fluid can be determined by measuring the resonant vibration frequency. Figure 2 compares the oscillating tube to a mass and spring assembly.

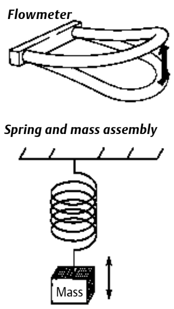


Figure 2. Density theory

$$\rho = \frac{k}{4\pi^2 f^2 V} - \frac{m(tube)}{V}$$

$$\rho \propto \frac{1}{f^2}$$

YPF examines and reduces actual losses

By using Coriolis Meters, YPF significantly improved its dynamic flow measurements, including all inputs to, and outputs from the refinery. A schematic of all measurement points is shown on the back. Stock measurements were also improved by making a number of changes to the operational procedures involved in the delivery and discharge of products to and from tanks.

After these measurement changes were made, YPF had confidence in the actual losses. Sources of real loss are evaporation and the flare stack, where gas is burned for safety or production reasons. The flare stack was the first target for reducing actual loss. Through better control of emissions to the flare system, YPF was able to reduce losses by 1.5 to 2%. YPF also installed ultrasonic meters to increase the accuracy of the flare gas measurement and improve the overall refinery balance.

Ultrasonic meters help complete the mass balance

Fluid density can also be determined using ultrasonic meter technology, because there is a known relationship between gas molecular weight and the speed at which sound travels through fluid. The relationship is basically linear, although somewhat sensitive to composition.

By measuring the volumetric flow and density of the flare gas, the ultrasonic meters can also provide a mass flow output. In this manner, YPF is now measuring all the major streams that contribute to the refinery balance on a mass basis. YPF is consistently measuring losses of 0.6 - 0.8%, down from above 5% several years ago.

Ultrasonic flowmeters employ sound waves to measure the velocity of a fluid moving through a pipeline. Transit-time ultrasonic meters transmit pulses, from a transmitting transducer, which propagate through the flowing medium to a receiving transducer. The time difference between how long it takes one pulse to travel upstream, and one to travel the same distance downstream, is used to calculate flow velocity.

Better fuel measurement can further improve mass balance

The primary areas in which YPF still sees opportunity to improve its mass balance is fuel consumption measurement. This includes both fuel gas and fuel oil, although the primary problem is assumed to be with fuel gas measurement. The fuel gas system uses process quality orifice meters, which are not recalibrated as process and fluid conditions change. A constant value is assumed for the discharge coefficient used in calculating the flow rate from the pressure drop. This discharge coefficient was determined using a calculation of expected average flow conditions. As a result, there can be significant errors in the fuel gas system flow measurements— a potential area for further mass balance improvement.

Coriolis flowmeters can be used for measuring the mass flow of gases, as well as liquids. YPF is now considering installing Coriolis meters on the fuel system to keep all measurements on a true mass basis. Because Coriolis meters are unaffected by changes in composition, measurement accuracy will increase significantly.

Conclusion

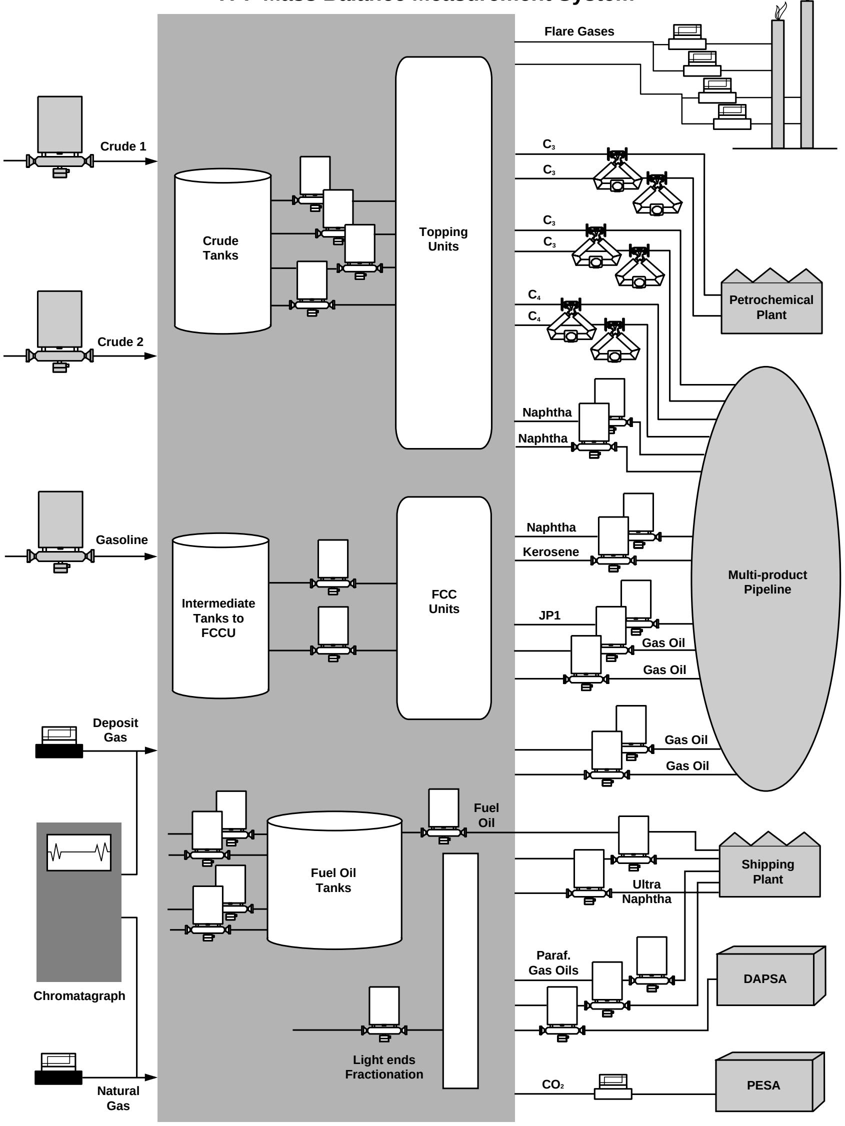
Refinery loss control has greater implications than just achieving a mass balance. The use of Coriolis technology to directly measure mass flow and density increases measurement accuracy and ultimately improves the refiner's ability to achieve a mass balance.

The continuous, real losses caused by inaccurate measurements also have a tremendous environmental impact. With more attention being paid to protecting the environment, scrutiny of loss figures will only increase.

To understand the magnitude of actual refinery losses, one can compare the oil losses from accidental spillage to the steady and continuous evaporative losses normally occuring at a refinery. The quantity of oil lost in the Exxon Valdez oil spill off the coast of Alaska is approximately the same quantity lost through annual evaporation at the average refinery. Although the evaporative losses do not make headlines and presumably do not cause the same level of environmental damage, they cannot be ignored. Environmental and government agencies are beginning to monitor refiners much closer. Legislation in some countries is requiring refiners to demonstrate the efficiency of their balance and loss control procedures. Such legal requirements are likely to expand in the future. As a result, refiners will find it increasingly necessary to report reliable loss figures, and to demonstrate their loss minimization efforts.

Improvements in Refinery Loss Control

YPF Mass Balance Measurement System



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