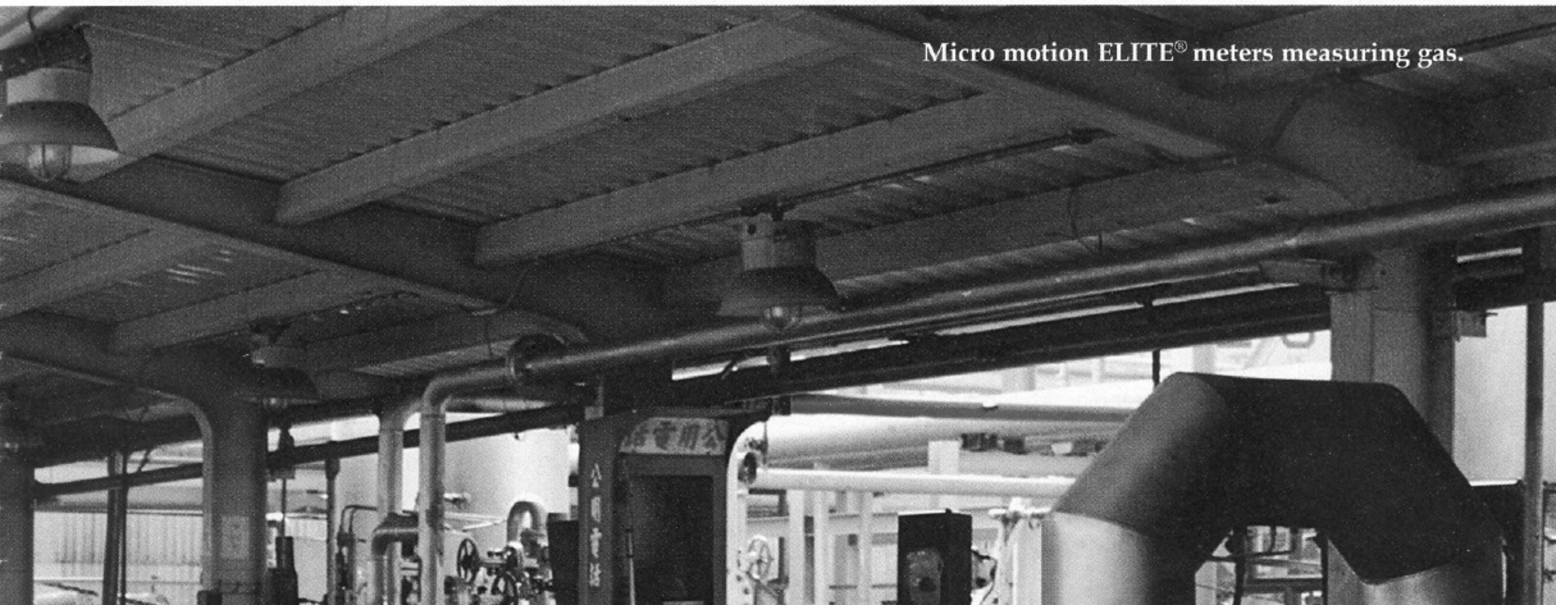
MEASUREMENT ECONOMICS



Micro motion ELITE® meters measuring gas.

Julie Valentine, Micron Motion, Inc., USA, and Miguel Bagajewicz, University of Oklahoma, USA, look at the economic impact of process flow measurement and the justification of data reconciliation and instrumentation upgrade.

The importance of accurate flow measurement to refining operations depends strongly on the type of application. There are applications where the need for accurate and precise measurement is well recognised in the refining industry. This would include custody transfer measurements, both at the inlet and outlet of the refinery, and product blending. It is easy to calculate the value associated with the custody transfer measurements, as this is the cash register for the refinery. Any inaccuracy in flow measurement will directly impact the bottomline.

The impact that accurate custody transfer measurement has on refinery losses is also easy to understand. The adoption of mass-based flow technologies such as Coriolis has aided many refineries in closing their mass balance and identifying areas of loss.

Table 1. Stream data

Stream	Measured flow rate (kg/h)	Standard deviation (kg/h)	Flowrate after reconciliation (kg/h)	Standard deviation after reconciliation (kg/h)
LPG	5122	77	5124	77
Gasoline	21434	322	21467	321
Naphtha	45680	685	45829	675
Kerosene	26084	391	26133	389
Diesel	73319	1100	73704	1059
AGO	50533	758	50715	745
LVGO-1	38515	578	38557	540
LVGO-2	18921	284	18932	280
HVGO-1	19835	298	19846	293
HVGO-2	23864	358	23880	349
HVGO-3	18187	273	18196	269
Wax	18097	271	18106	268
Vacuum residue-1	15141	227	15154	225
Vacuum residue-2	20245	304	20268	299
Vacuum residue-3	12650	190	12659	188

But what about the need for accuracy in process measurements, for example the FCC unit, the crude unit, or the coker? Traditionally, less accurate flow devices are used for the process flow measurements as the need for accurate flow measurement is unclear. Although it is generally recognised that in order to evaluate the performance of the process unit to calculate conversion, catalyst selectivity, and yields, the flow measurements must be accurate and the unit mass-balanced, it is a more complex problem to attach an economic value to that accuracy. What impact does the accuracy have on data reconciliation, and what relationship is there to profitability?

To answer this question, the economic benefits of instrumentation upgrades and data reconciliation have been examined in a recent conference article.[1]

Economic value of precision

A typical refinery consists of several tanks that receive the crude, several processing units, and several tanks where products are stored. When measurements of the products are made, or better, when these are obtained through data reconciliation, some corrective actions are performed. Assume the simplest scenario in which the operators perform corrective actions only when measurements indicate that the flowrate of products is below the targeted production. Thus, when the flowrate is above the target, no correction is made, but there is a 50% chance that the real flowrate is actually below the target. In such a case, statistics can be used to infer the expected financial loss associated. A few manipulations using measurement and flowrate distributions help produce the following expression for the downside expected financial loss (DEFL).

$$DEFL=\gamma K_S T\sigma$$

In this expression, $\gamma=0.1995$, T is the time horizon, σ the standard deviation of either the measurement or an estimator obtained through data reconciliation. Finally, K_S is the product cost, but in the case where large inventories are kept, this is a number related to inventory costs.

A simplified derivation of these expressions can be found in an article by Bagajewicz and Markowski[1] and the complete theory in an upcoming article.[4]

Using the above concept one can easily evaluate the economic value of purchasing a data reconciliation package and/or engaging in an instrumentation upgrade project. Indeed, assume that σ^0 and σ^R are the standard deviation of the measurement and the estimators obtained using data reconciliation, respectively. Then the difference in expected downside financial loss is given by:

$$\Delta\ DEFL=\gamma K_S T (\sigma^0 - \sigma^R)$$

which can be used to obtain a net present value by adding it using the proper discount rate throughout several years and subtracting the costs of the software, since it is well known that the addition of instrumentation improves redundancy and reduces σ^R.

Casestudy

The example of an existing 80 000 bpd crude unit consisting of a prefractionation column, an atmospheric tower and a vacuum unit will be considered. The unit is well instrumented, or at least sufficiently instrumented so that data reconciliation is possible and it processes a heavy crude. Table 1 depicts the flowrates, standard deviation of the instruments installed and the values obtained after data reconciliation is performed using

Table 2. Effect of new flow meters on savings, NPV is over a five year period

	New instruments with the same precision as the installed ones (σ=1.5%)		New instruments are Coriolis meters (σ=0.1%)	
Location of new sensors	NPV without originally installed data reconciliation (US$)	NPVdata reconciliation is already in place (US$)	NPV without originally installed data reconciliation (US$)	NPV data reconciliation i is already in place (US$)
A new instrument added to each stream of Table 1	2 088 015	1 851 394	6 717 940	6 481 319
A new instrument added to each stream of Table 1, except vacuum residue-3	2 098 670	1 862 049	6 729 940	6 493 318
A new instrument added, to each stream of Table 1 except vacuum residue-3 and vacuum residue-2	2 071 110	1 834 489	6 618 863	6 382 242
A new instrument added to each stream of Table 1, except in all vacuum residue streams.	2 052 817	1 816 195	6 537 530	6 300 909

those instruments for some selected streams.

For these products we considered the actual local values of transfer prices (based on a cost of crude of 30 US$/bbl) and determined the downside financial loss for the existing instrumentation without the aid of data reconciliation is approximately US$ 7.36 million, while after applying data reconciliation it reduces to US$ 7.12 million. This renders a net present value (over only five years) of US$ 236 621. This might justify the purchase of a data reconciliation package.

Net present value of new instrumentation

Consider adding an additional instrument of 1.5% standard deviation to some streams. The results are illustrated in Table 2. The first column of this table indicates which instruments have been added. The second column indicates the net present value of the project using new instruments of the same precision as those installed (1.5%) assuming no data reconciliation package has been installed, whereas the third column indicates the net present value for the case where the plant already has data reconciliation installed and in use. Table 2 also depicts in the last two columns the substantial increase in economic value obtained with the addition of Coriolis meters.

It is quite obvious that after a certain point the addition of new instrumentation or the replacement of existing instrumentation with more precise instrumentation reaches the maximum amount of investment that a company is willing to make or the net present value starts to decline. This is true in all cases depicted in the table. While in this example we have explored only a few options, it is quite clear that a simple enumeration of all possibilities is time consuming and even impractical. Consider only 15 potential places for new instruments. This means that there are 2^{15} (32 768) different cases to explore, which is already unmanagable by simple enumeration. If we considered half of the potential places in this plant, we would have approximately 10^{10} different cases to evaluate, which is virtually impossible. Thus a systematic search of the optimal solution needs to make use of mathematical modelling and optimisation theory. This is explored by Bagajewicz in his book and a recent article.[2, 3]

The solution then for determining the net present value of upgrading instrumentation and implementing data reconciliation consists of several steps. The requirements of such a solution would include the following:

- Analysis of the uncertainty of existing measurement systems.
- Analysis of the maintenance costs associated with the existing measurement systems.
- Determination of the optimal number of additional measurement points or increased precision of flow measurements through NPV calculations.

Through such an analysis, one will find several advantages in applying Coriolis-based flow measurement in strategic locations. Since Coriolis meters measure mass flow directly, they are not influenced by changes in fluid properties. They are extremely accurate, and Coriolis meters will maintain their accuracy, even when conditions change, such as when processing a different crude oil.

The cost of maintaining accurate measurement is also reduced significantly with the use of Coriolis flow measurement. Since there are no internal moving parts, there is no wear and no requirement for periodic recalibration in order to maintain accuracy. All of this must be considered when calculating the NPV of the instrumentation upgrades.

Another aspect of maintaining the reliability of the measurements on a processing unit is in the instrumentation diagnostics. Whether the flow measurement is made with a Coriolis meter, a dP transmitter, or a vortex meter, a rich source of diagnostic information about the health of the device is available in the newer products offered by instrumentation and control companies such as Emerson Process Management. Such diagnostic information can be used to predict which instruments need maintenance or calibration, and can also perform an audit trail to identify the instruments that have been calibrated or that people have touched.

How a Coriolis meter works

The Coriolis effect was discovered by Gaspar Gustav de'Coriolis in the late 1700s. In essence, this force is generated when an angular velocity comes in contact with a forward motion. The forward motion is the product flowing through the meter. Vibrating the flow tubes at their natural frequency generates the angular velocity. This oscillation can also be used to determine density.

To measure the Coriolis effect, the meter will have a pickoff coil on each side of the flow element. The pickoff contains a coil and a magnet. As the coil moves through the magnetic field from the vibration of the tubes, voltage is produced. This voltage produces a sine wave.

By comparing the sine wave generated by the inlet and outlet pickoffs, mass flow rate can be determined. If there is no flow present, the time difference or ΔT between the two pickoffs will be zero as shown in Figure 1. However, there will be a time delay between the two pickoffs as flow begins. The higher the flow rate, the greater the ΔT between the two pickoff coils. This comparison, called phase shift, is directly proportional to mass flow rate.

Conclusion

As plants are becoming more and more automated, data fed to the control systems, data reconciliation systems, and higher level planning and scheduling systems must improve. There are a variety of instruments, tools and services available to help refiners improve their existing systems. To justify the investment though, it is critical that the relationship between data integrity and value is well understood.

References

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Enquiry no: 18