

# CONTROL ENGINEERING

Vol. 57 No. 9

NOVEMBER 2010 Covering control, instrumentation, and automation systems worldwide

## Custody Transfer: Flowmeter as Cash Register

When bulk liquid or gas products change hands, everyone has to agree on the quantity and the product quality. This puts very special demands on instrumentation.

**Emerie Dupuis and  
Gerard Hwang**  
*Daniel Measurement  
and Control,  
Emerson Process  
Management*

Every process plant in the world takes in bulk raw materials and fuel from tanker ships, railroad cars, tanker trucks, or pipelines. Refineries, chemical plants, pharmaceutical companies, and a host of other industries have to measure raw materials and finished products accurately, because they pay for what comes in and get paid for what goes out.

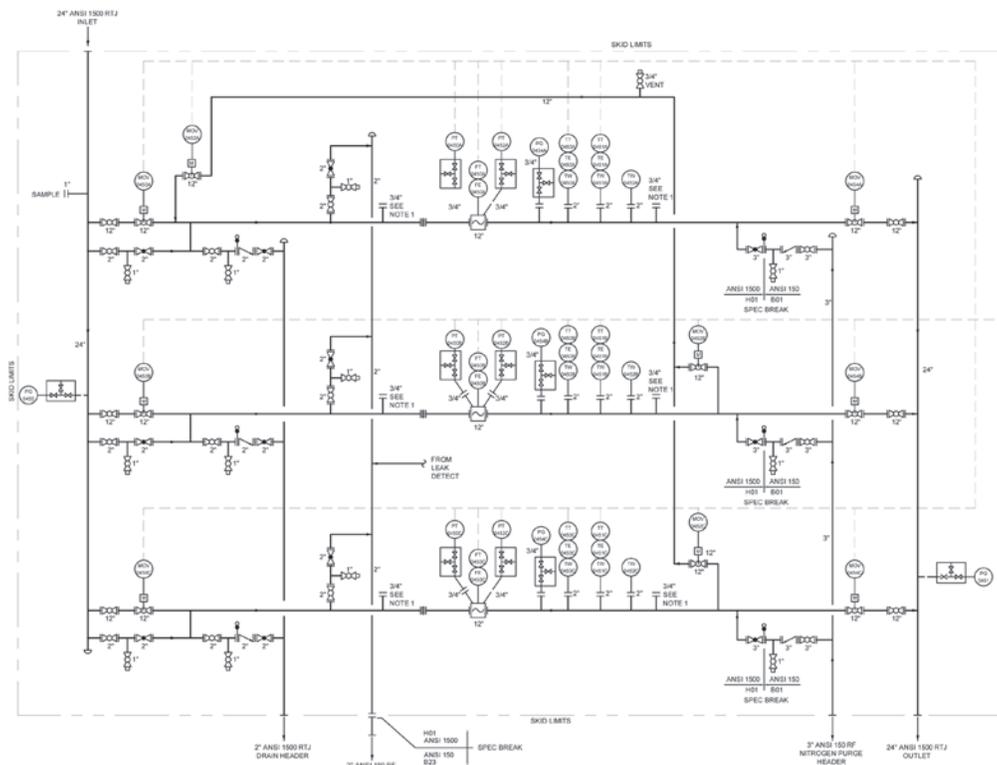
Transportation companies—the ones who own the

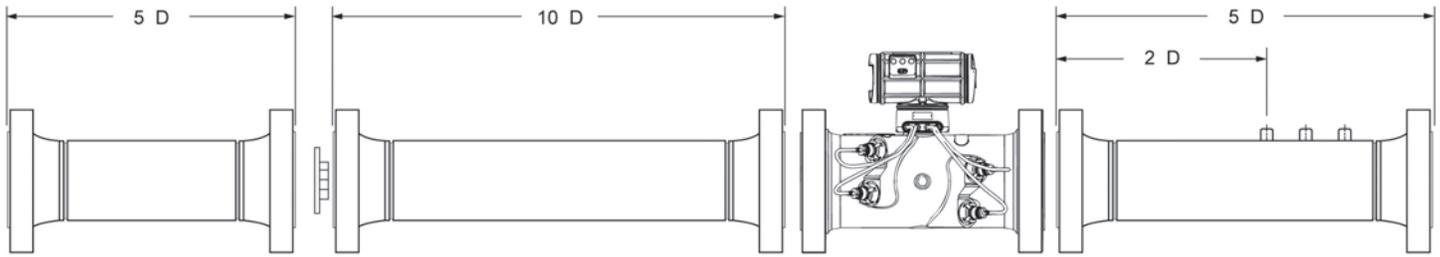
tankers, railroad cars, or pipelines—also get paid for the amount of materials they move. Companies that push gas through a pipeline, for example, operate on a slim margin of a few pennies per MCF (million cubic feet), so they want to know exactly how much is involved.

Whether it is oil, gas, or chemicals, a tiny error of even 0.25% in the flow measurement of materials being transferred can cost a company millions of dollars in one year. A very large custody transfer system can meter \$6,000,000 worth of natural gas per day, or \$2.2 billion per year. If the measurement is off by 0.25%, that's an error of \$15,000 per day or \$5.5 million per year in somebody's favor.

The terms custody transfer and fiscal metering are often interchanged. Custody transfer takes place any time fluids are passed from the possession of one party to another. It refers to metering that is a point of a commercial transac-

*Figure 1: As this P&ID illustrates, a custody transfer metering system has multiple flowmeters, valves, meter runs, flow provers, flow computers, thermowells, and analyzers. Specially designed measurement and control systems such as Daniel's DanPac, provide the necessary records and auditable values for custody standards.*





**Figure 2: Typical installation of an ultrasonic meter has a five diameter (5D) settling zone approach section ahead of the conditioner plate and a ten diameter approach section between the plate and meter. The 5D discharge section allows sufficient space to locate a thermowell 2-5D downstream (typically 3D).**

tion such as when a change in ownership takes place.

In general, custody transfer involves:

- Industry standards;
- National metrology standards;
- Contractual agreements between custody transfer parties; and
- Government regulation and taxation.

Custody transfer metering systems must meet requirements set by industry bodies such as AGA, API, or ISO, and national metrology standards such as OIML (International), NIST (U.S.), PTB (Germany), CMC (China), and GOST (Russia), among others.

A number of flowmeter technologies are used for metering: orifice (differential pressure), turbine, positive displacement, Coriolis, and ultrasonic. While the same basic technologies are used for normal process control, the very large volumes involved in most custody transfer applications demand accuracy typically greater than for process metering, because it is the cash register.

For instance, liquid custody transfer meters used to measure refined hydrocarbons have accuracy of  $\pm 0.125\%$  or better, and repeatability in the range of  $\pm 0.02\%$ .

Custody transfer requires an entire metering system that is designed and engineered for the application, not just flowmeters. Components of a custody transfer system typically include:

- Multiple meters/meter runs;
- Flow computers;
- Quality systems (gas chromatographs for to measure energy content of natural gas and sampling systems for liquid);
  - Calibration using in-place or mobile provers for liquid, or master-meter for liquid or gas; and
  - Supporting automation.

Figure 1 illustrates a typical liquid custody transfer skid, including multiple flowmeters and meter prover. Provers are used to calibrate meters in-situ. Proves are performed frequently, typically before, during, and after a batch transfer for metering assurance.

### Ultrasonic and Coriolis flowmeters

Custody transfer measurements have been around for a long time, and were often based on orifice flowmeters, turbines, and positive displacement meters. These flowmeters induce pressure drop or have moving parts that wear out.

Over the past ten years, Coriolis and ultrasonic

meters have become the flowmeters of choice for custody transfer in the oil and gas industry.

Ultrasonic meters provide volumetric flow rate. They typically use the transit-time method, where sounds waves transmitted in the direction of fluid flow travel faster than those traveling upstream. The transit time difference is proportional to fluid velocity. The average axial velocity multiplied by the area of the pipe then gives the uncorrected volumetric flow rate through the ultrasonic flow meter transmitter. Mass flow rates can be determined in conjunction with densitometers.

Ultrasonic flow meters have negligible pressure drop, have high turndown capability, and can handle a wide range of applications. Crude oil production, transportation, and processing are typical applications for this technology. Their full-bore configuration can match the pipe diameter to minimize compression or pumping energy required to move oil or gas over thousands of pipeline miles across continents. Newer meters extend the temperature and viscosity range to address applications like the heavy crudes found in oil sands and oil shale. Advanced models have extensive diagnostics which help reduce measurement uncertainty and simplify operations. Spool-piece ultrasonic meters are commonly available in 2 to 24 in. pipe sizes.

Coriolis flowmeters provide direct mass flow measurement, with high accuracy and repeatability over wide turndown ratios. They maintain those qualities even when fluid conditions such as density, viscosity, and composition change frequently. Micro Motion first introduced Coriolis meters to the market in the 1970s. In 2002, after decades of successful measurement, the American Petroleum Institute (API) approved their use for custody transfer applications (API Chapter 5.6). Coriolis meters are used on lines from less than 1 to 12 in.

### In search of accuracy

Accuracy refers to the closeness of the measurement to the true or accepted value. Each device (flowmeter, pressure transmitter, temperature sensor, BTU analyzer, etc.) has its manufacturer-stated accuracy specification and its tested accuracy. Uncertainty takes all the metering system factors that impact measurement accuracy into account. So, two  $\pm 0.125\%$  accuracy flowmeters could be used in two different metering systems that ultimately have different calculated uncertainties due to other "things" in the system that

affect flow calculations. Uncertainty even includes such factors as the flow computer's A/D converter accuracy.

When using an ultrasonic flowmeter (USM) for custody transfer of natural gas, here are some of the items that must be considered:

**Meter tube alignment:** The piping leading up to and away from the ultrasonic sensor must be aligned perfectly. AGA 9 allows the tube-to-meter match to be within 1.0%, so for a tube with a bore of 11.75 inches, AGA allows a misalignment of up to about 0.125 in. This is a huge gap, and a USM can normally deal with the mismatch if the registration is concentric. Recent tests show that eccentric connections that leave edges can cause errors of up to 0.2%. Most good tube manufacturers will align to within a few thousandths of an inch.

**Distance from control valve:** Noise from control valves can interfere with an ultrasonic sensor's measurement, so a good practice is to place valves downstream of meters (if possible), put as much distance as possible between valves and meters, and put some bends in the piping to reduce noise. "Noise trap" tees are very effective in reducing valve noise. In a similar fashion, Coriolis meters can be affected by vibration, so they need their own form of protection.

**Headers:** A typical custody transfer system has multiple flowmeters installed across a single header. This arrangement can allow for one flowmeter to occasionally be used as a "master meter" or reference meter, while the other flowmeters are routinely used to measure fluid flow. It also allows an individual meter run to be isolated so that it can be serviced, removed, cleaned, or calibrated without shutting down the line.

**Sizing headers:** Cost increases as the header size increases, but performance suffers if headers are undersized. Header sizing sounds like a very basic concept that every engineer should know, but we have seen a large number of incorrectly sized headers on legacy systems.

**Temperature sensors:** The location of temperature sensors is critical for maximum accuracy. (See figure 2.) For gas, AGA 9 recommends the thermowell be installed between two and five diameters downstream of the flowmeter in a uni-directional system, and three diameters from the meter in a bidirectional installation.

**Flow provers:** One flowmeter is designated as the flow prover. (See figure 3.) This is a flowmeter of exceptional accuracy, and one that has been calibrated and tested recently. In some cases, for large pipe sizes (30 in. and larger), the flowmeter has to be shipped to a calibration facility capable of handling something of that size. For smaller units, portable flow provers can be brought to the plant site to serve as a calibrator.

During operations, a meter to be tested is aligned in series with the master meter prover by way of valving. The flow computer compares the output of the two flowmeters to calculate the error between them. A resulting correction factor is then calculated and applied to the computations for the meter under

test. Each meter in a multi-run metering system can be likewise proved as often as is necessary to ensure maximum measurement accuracy.

**Flow computers:** A flow computer is the actual cash register of a custody transfer system. The flow computer is typically the only device directly connected to the measurement devices (meters, transmitters, gas chromatograph, etc.). The flow computer performs all the necessary industry-standard flow calculations. For example, the Daniel S600 flow computer can support up to 10 individual meter runs, or 6 meter runs and a prover.

**Site design:** When installing the flowmeters at the site, prior planning should ensure that there is room available to clean the meters and use extractor tools to remove the transducers when necessary. The site should also provide access for service vehicles, portable flow provers, and calibration equipment. Gas metering skids are relatively straightforward compared to liquid systems, which require consideration of proving meters in place and under operating conditions, such as having a skidded pipe prover connected to the metering system. Other circumstances may require providing proving take-offs on the meter skid for connection to a portable prover, or call for having a "master meter" on the skid that can be placed in series with a meter to be tested by moving a few valves.

When proving is a consideration, additional factors become extremely important, such as mak-



*Figure 3: A flow prover is installed in a custody transfer system to provide the most accurate measurement possible. It is used to calibrate the other flowmeters before, during and after a transfer.*



*Figure 4: Completed meter on a skid, ready for installation. The tubes are factory aligned meter-to-tube, conditioner plates and approach/discharge spools are concentrically aligned, and bolts are drawn up in sequence. All flowmeters, thermowells, analyzers and other equipment have been installed, wired and calibrated.*



*This photo gives a better impression of how large and heavy (More than 40 tons.) a full-scale pipeline system can be. The fact that it may handle between \$5 and \$10 million worth of natural gas each day explains why accuracy and repeatability are so important. Error levels that would be tolerable in a process plant context can cost one side or the other tens of thousands of dollars in a matter of hours.*

ing sure all key valves are double block & bleed so no flow goes around the prover by getting through a leaking valve. Depending on the type of meters being used, liquid systems can also be more sensitive to pulsation or flashing of liquid product causing gas formation in the flow.

#### A simple skid approach

Many custody transfer and fiscal metering systems are built on skids and transported to the customer's site. (See figure 4.) This allows the system to be designed, fabricated, and assembled in a clean, dry area, and then dropped in at the site.

A skid system package may contain multiple flowmeters and meter runs, gas chromatographs to calculate energy content of natural gas, sampling systems for liquids, flow computers, temperature sensors, data acquisition and control equipment, and a communications system. It is important to keep in mind that the measurement system as a whole, must meet custody standards.

A qualified skid builder should have all the expertise needed to size tubing and headers, align them properly, ensure that no valve noise, vibration or flow disturbances will adversely affect the meters, install flow conditioners where needed, perform flow testing and calibration, and prepare the assembly for trouble-free shipping to the customer site. This last step is extremely important, because skids can be very long and heavy, and must be supported and transported carefully to prevent damage to the piping or meters.

Building a custody transfer system on site or

upgrading an existing installation is certainly possible, however both of these solutions can be disruptive to the plant and would have to be performed during a shutdown period.

#### Don't try this at home

Building a custody transfer system requires extensive knowledge of various regulations, flow characteristics, flowmeter specifications, and a host of other factors. While a typical process control engineer may be quite knowledgeable in some of these areas, the vast amount of specific application knowledge needed can be daunting. Designing and building a custody transfer system is best left to experts.

Fortunately, a number of system integrators, skid builders, and flowmeter manufacturers have the experience and knowledge needed to provide a complete turnkey solution package for such an application.

When launching a project, we begin the process by analyzing the customer's needs in depth. Many questions need to be answered, including:

- Expected flow conditions;
- Area safety rating;
- Anticipated pulsation, noise, and vibration;
- Unidirectional or bidirectional flow;
- Required flowmeter size;
- Need for flow conditioners;
- Chemical or environmental requirements for special materials needed;
- Temperature, pressure and flow ranges;
- Ambient noise conditions;
- Applicable mechanical standards;
- Governing safety standards; and
- Horizontal vs. sloped flowmeter mounting.

Beyond the hardware, you must consider the ability of the site to accommodate the system; the measurements and flow calculations needed; the control system with which it will communicate; and service and calibration requirements before, during and after installation.

After installation at the site, the provider must commission and startup the system, including connections to the plant control system. Once operating, the unit will need ongoing technical and full life-cycle support in accordance with the original purchase agreement.

An effective custody transfer system that is well maintained and calibrated will make for smooth product flow and avoid disagreements between the participating companies on product quality and quantity. **ce**

*Emerie Dupuis and Gerard Hwang are with Daniel Measurement and Control, division of Emerson Process Management.*

#### ONLINE

For more information, visit:  
[www.daniel.com](http://www.daniel.com)  
[www.emersonprocess.com](http://www.emersonprocess.com)  
[www.micromotion.com](http://www.micromotion.com)

Posted from *Control Engineering*, Month 200X. Copyright © CFE Media. All rights reserved.  
 Page layout as originally published in *Control Engineering* has been modified.

#1-28342802 Managed by The YGS Group, 717.505.9701. For more information visit [www.theYGSgroup.com/reprints](http://www.theYGSgroup.com/reprints).