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Introduction

The purpose of this paper is to review the criteria used in the design of liquid measurement stations. After reviewing this paper, the reader should have a better understanding of the pivotal items to consider in this design, as well as an appreciation for the major components which are a part of liquid metering stations.

Design considerations can be separated into four major areas: accuracy, space, pressure loss, and cost. Major components will be reviewed as they constitute the metering skid, the prover skid, and the instrumentation controls. In most cases, the metering systems reviewed are used in high-accuracy, custody transfer applications. Typical applications include tanker and barge loading and offloading, pipeline to storage measurement, LACT (Lease Automatic Custody Transfer) units, metering into and out of refineries, ship bunkering, and low-temperature applications such as LPG or Butane.

Accuracy Considerations

Systems can be designed to have different degrees of overall accuracy. In some cases this is defined by local weights and measures requirements, the end user's standards, or the national standards to which the end user must strictly adhere. The overall system flow capacity must be clearly defined, resulting in the proper selection of the number and sizes of meter runs. This will insure that the meters are operating not only within their design capacity, but also at or near their ideal flow rates. If required, the meters can be supplied with premium linearity to ensure the highest degree of overall accuracy is achieved. The low flow rate also needs to be reviewed to ensure the meters still maintain their required accuracy under these low flow conditions. Flow circumstances may require that a smaller meter be included in the design to be utilized during the start-up and topping-off operations. Viscosities also affect some meter's rangeability and accuracy. This information is usually listed in the meter manufacturer's specification data sheets published by the manufacturer.

Proving methods and frequency of proving will greatly impact the system's accuracy. The standards associated with these are, again, normally set by local or national authorities. The majority of high-accuracy custody transfer metering stations includes some type of a stationary volumetric prover. The exception to this would be LACT units, which are normally calibrated with a por-

table prover. The different types of provers commonly used for these applications will be reviewed later in this paper. Some applications have required that a smaller prover be supplied along with the larger prover. The smaller prover is then used in combination with a master meter to confirm the accuracy of the main prover on a regularly scheduled basis. Frequency of proving is determined by local requirements, changing conditions, and possible wear due to corrosive products. In all cases, provers are calibrated and waterdrawn at the factory (usually to N.I.S.T.) and calibration certificates should be supplied with the final documentation package. Today's microprocessors allow for automatic, on-line proving; can calculate a meter factor; and generate the required proving report.

System designs can include different types of compensation, such as temperature, pressure, and density. Temperature compensation is the most common and this can be accomplished through mechanical means (ATG) or through today's microprocessor flow computers. Microprocessors will have a much faster response time and allow the actual A.P.I. formulas to be loaded into memory. Both of these capabilities result in a higher overall degree of accuracy.

Meter selection type can also affect the system accuracy. Most liquid meter systems are designed around either positive displacement (PD) or turbine meters. Operating conditions such as flow rates, products, viscosity, temperature, pressure, and type of service should all be considered in the final meter selection.

Space Considerations

If space is very limited or expensive (such as on an offshore platform), then it can become a prime factor in the overall system design and selection of major components.

Typically, a turbine meter system will require more space than a PD meter system, due to the requirement for the upstream and downstream straightening sections. However, the application may still require that turbine meters be utilized. The size and number of meters will also affect the overall meter skid size.

Not only the selection, but the design of the prover will have an impact on the prover skid dimensions. Small volume provers would normally require the least space. Other provers (bidirectional, unidirectional) can be double-looped for a more compact design. Launch chambers can be at 90 degrees, 45 degrees, or straight through, all varying the prover skid height and length.

The prover and meter skid can be designed into one integral package to reduce space. This design may be more costly (extra engineering, piping, and design support), but if space is the prime concern, this may be the solution that you require for your application.

Pressure Loss Consideration

Pressure loss costs money in terms of wasted energy and capacity. Increasing the size of the headers, meters, and valves will all reduce the pressure drop through the system and prover. Supplying 100% full-port opening valves versus 70% opening valves will reduce the pressure loss. But is the extra associated cost for your application worth this change? Strainer bodies and the inlet/outlet nozzles can also be increased to reduce pressure drop. Strainer mesh size will likewise impact the pressure drop. Special launch chambers and bypasses on the prover can be investigated for additional pressure loss reductions. The overall system pressure drop must be considered at the maximum flow rate of the system with one meter run being proved. This will ensure that the pressure drop through the prover is included in this calculation.

Cost Considerations

Overall system cost is usually the prime consideration by the end user in his design. The final selection of the alternatives already reviewed will have a significant impact on the final price. Major cost items to consider include:

Meter Selection Type

PD's versus turbines. Typically, on larger size meters turbines will be less expensive, but will they meet the other criteria for this application? There would also be the trade-off for the larger meter skid if turbines are selected.

Prover Selection Type

Bidirectional provers are utilized in the majority of applications. Others to consider include small volume provers and unidirectional provers. Alternatives, including the use of a single-loop design or a double-loop design, also need to be investigated.

Compensation

The degree of compensation (temperature) will impact the system cost. Mechanical compensation will normally be less expensive, however, with this method of compensation it will prove difficult to achieve the accuracy available with today's electronics. The choice becomes accuracy versus cost.

Automation

Normally, the higher the degree of automation, the greater the initial cost, however, the higher level automation-type systems will probably save time (manpower, loading duration), improve the accuracy, improve safety, and provide management with more current and detailed reporting.

Safety

Safety requirements — beginning with the alarm system through the construction codes, offshore codes, drip pans, and safety relief valves — will all impact cost.

Shipping

Shipping costs can be extremely important, especially if overseas transportation is required. A few more dollars spent in proper design may allow the system to be broken down for shipment, greatly reducing the overall shipping cost.

Standardization

Standardization (if you have more than one system) on meter sizes, valve sizes, and the type of instrumentation may allow you to reduce the quantity and value of operational spare parts requirements.

Other

It may be more expensive to design grading, walkways, and items such as lights and overhead cranes into the initial systems package. However, these particulars may save a great deal of money in the field during start-up, recalibration, or when maintenance on major components is required.

Metering Skid Components (See Figure 1)

The inlet and outlet header of the metering skid are used for the field connections to the inlet and outlet piping. The entire system flow capacity will travel through these headers, and therefore, they must be properly designed to handle this flow capacity. Velocity through these headers is normally held at 13 feet per second or

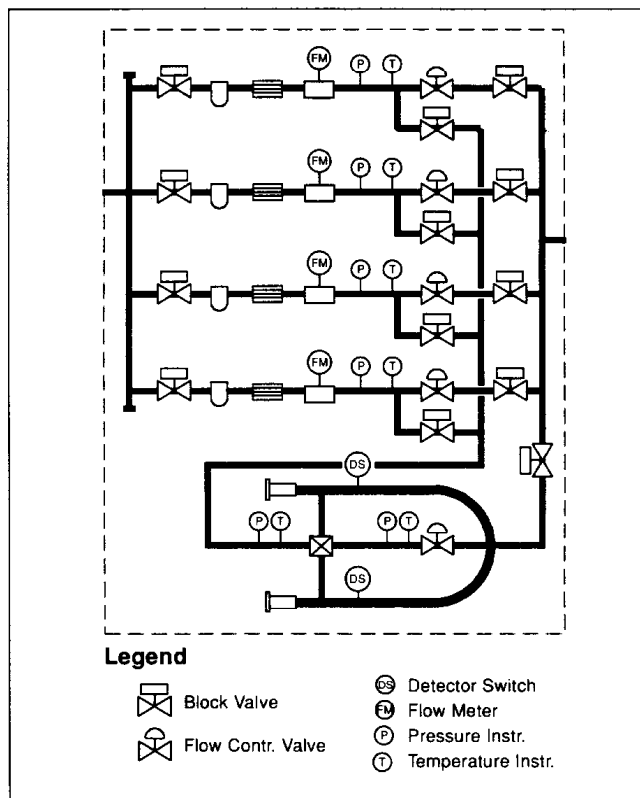


Figure 1

less. Headers can be extruded, tees, or fabricated. Location of in-field connections needs to be identified. Typically, these can be at either end of the header or in the center. The outlet header will also have a connection for the prover return line. The most well-balanced system is typically to allow for the flow to enter at one end of the inlet header and exit through the opposite end of the outlet header. This is sometimes referred to as the "Z" configuration.

Coming off the inlet header are the flanged connections for the individual meter runs. The system flow is split here through two or more meter runs. The components of each meter run will be identical.

The first meter run component is normally an inlet valve. This valve is customarily a gate-type valve and its main purpose is meter run isolation for maintenance (clogged strainer, equipment repairs, etc.).

Since this valve is infrequently used, it is usually supplied with a manual operator. It is not mandatory that this valve be of the high integrity, double-block-and-bleed type necessary for proving.

Deaerators (optional) may be required if there is the possibility of entrained air (heavy crude oils) or large batches of air, as seen when completely off-loading a ship or a storage tank. Deaerators can be supplied with baffle plates and a number of air release heads. The larger diameter in the body of the deaerators reduces the velocity of the product, allowing the air bubbles to accumulate on the baffle plates and move to the top of the deaerator. From here, the air release heads will allow the trapped air to escape.

Strainers are supplied to act as a protective device. As previously mentioned, the body sizes and flange connections can be altered to reduce pressure drop. If deaerators are not included in the system, then an air release head would normally be mounted on the top of the strainer. Various types of quick-opening closures are available for these strainers. This allows for quick access to clogged strainers or for the replacement of damaged strainer baskets. Delta-P switches can be included to check for clogged strainers. Drain valves are normally supplied on the strainers, as this is a low point of the system.

The operating conditions and products will help with the selection of the type of meter (positive displacement or turbine meters). If turbine meters are being utilized, then upstream and downstream straightening sections will also be included. As a minimum, it is recommended that a backup counter and a transmitter be mounted on the top of the meters. The entire system is built around the meter and proper care should be exercised in the selection of the type and size of the meters. The meter size (flow rate) will determine the size of the prover. Multiple meter runs are supplied to add flexibility, rangeability, and support the most economical cost alternative. The majority of custody transfer systems is supplied with a spare meter run. The system can then operate at full flow capacity with a backup or standby meter in case of damage or maintenance requirements. The spare meter run should be rotated in and out of service with the other meter runs.

Temperature and pressure gauges and transmitters are located downstream of the meter. They are used for net volume corrections and for determining the correct meter factor when proving.

Flow control valves (butterfly type) serve a number of purposes within the meter system. They will ensure that the meter is flowing within its specified operating range. They will, likewise, ensure that the system flow is equally dispersed through the various on-line meter runs. On light products, such as LPG's, they will maintain back pressure on the meters to prevent flashing.

Each meter run has a connection to the prover inlet header. Only one meter product flows through the prover at one time; therefore, the prover header is designed to handle a single meter run flow rate.

Downstream of the flow control valve and on the inlet to the prover header are located high-integration, double-block-and-bleed valves. The valve located on the meter run serves two purposes. The first is to isolate this meter for proving. The second is to isolate (working with the meter run inlet valve) the meter run for maintenance. This valve is normally supplied with an electric or hydraulic actuator for remote operation, allowing for automatic proving. The integrity of these valves during proving can be verified through the double-block-and-bleed feature. The double-block-and-bleed valve on the prover inlet ensures that during proving, no product from other meter runs (those not being proved) can bypass this valve and leak into the prover. If this were to happen, the meter factor of the meter being proved would be incorrect and, most likely, you would not be able to obtain a repeatable and acceptable meter factor.

Other items to consider in the meter skid design include the support structure, electrical wiring, conduit, signal cable, junction boxes, utilities availability (power, air, hydraulics), thermal relief valves, walkways, grating drip pans, and the drain system. Lifting eyes and spreader bars can be supplied for transporting and positioning the system in the field. Anchor and bolt holes should be properly located to match the field support structure.

Prover Skid Components (See Figure 1)

The prover is sized to handle the maximum flow through one meter run. Provers can be mounted on the meter skid, but generally are loaded on their own skid foundation. These can be either fully skid-mounted, or semiskid-mounted. Common to most provers are detector switches, a sphere or piston, exchange valves, and a calibrated or certified measuring section. Prover inlets and outlets would include pressure and temperature instrumentation for either manual or automatic proving. Most prover internals have some type of a coating (such as an air-dried epoxy) for protection and a smooth flow of the sphere through the measuring section. In extremely severe conditions (product or temperature), this coating may require a special material and to be baked onto the internal surfaces. Vents and drains are usually supplied at the high and low points of the provers. To ensure a stable temperature during proving conditions, the prover can be heat-traced or insulated. If this is

required, then usually all piping from the meter downstream through the prover and back to the prover return line will also be insulated or heat-traced. The four major types of provers incorporated into custody transfer meter stations include:

- Bidirectional (Bidi)
- Unidirectional (Uni)
- Low Temperature Piston
- Small Volume

Bidi provers can be of the straight-type design, single-loop, or double-loop. These provers incorporate a four-way valve to reverse the fluid flow and to launch the sphere into the measuring section. An area of prerun length is included, preceding the detector switches, to ensure the four-way valve is properly sealed prior to the sphere making contact with the first detector switch. Launch chambers are normally at a 90-degree angle to the measuring section, but can be at 45 degrees or parallel to the measuring section. The design should require that one launch chamber be supplied with a quick-opening closure for removal and inspection of the sphere. To ensure that no product bypasses the sphere, it is normally sized a few percent larger than the inside diameter of the measuring section pipe.

Unidirectional provers operate under the same principle as bidi provers, except that the product flow is always in the same direction. Uni provers incorporate an interchange valve to capture, seal, and launch the sphere. Uni provers can reflect cost savings on larger meter sizes.

Low temperature piston provers (-50 degrees F) are used to measure products such as LPG and Butane. The principle is the same as the straight-type bidi provers. However, they incorporate a piston (in place of the sphere) and special low temperature materials for the pipe and fittings. On this type of prover, the launch chambers are in line with the measuring section and sized with the same pipe diameter.

Small volume provers are being accepted and used in custody transfer applications. Some of their advantages include size, space, weight portability, full automation, and the ability, with a single prover, to calibrate numerous sizes of meters. Offshore platforms have proven ideal for the use of small volume provers. These provers use a piston and optical or laser detector switches.

Instrumentation Controls

Instrumentation to control the metering system can be classified into three major types: local, discrete, and fully-automated.

Local instrumentation would be used on LACT-type systems. This equipment may include mechanical or electronic temperature compensators, totalizers, transmitters (for proving, sampling) and a ticket printer. These would normally be unmanned sites, operating 24 hours per day.

Discrete instrumentation could be of the CMOS (Complimentary Metal Oxide Semiconductors) type where one instrument is dedicated to each function. These instruments would be housed in a control panel located in a remote-controlled environment. The panel would

probably include an alarm annunciator system and a mimic panel. This type of system control is sometimes referred to as "semiautomatic." Each instrument is dedicated to one function: one for totals, one for temperature correction, one for batching, one for flow control, etc. Valves are normally opened and closed with pushbuttons located on the mimic panel.

The vast majority of systems being supplied today are of the fully-automated type. With the enhancement of microprocessors, these systems are capable of functions such as:

- Redundancy.
- Flow control.
- Automatic proving.
- Automatic meter factor calculation.
- Meter linearization.
- Customized reports and alarm systems.
- Graphics display of on-line activities.
- Interface to other computer systems.
- Batch control.
- Enhanced safety and security.

Such systems are normally operated from a keyboard and a VDU. The panel-mounted instruments pose as a backup to this supervisory system. Two printers are normally requested: one for reports and one for event logging. When alarms occur, this system can be programmed to shut the entire meter station down in a safe, secure sequence.

General

Other equipment which is sometimes included in the meter system design includes samplers, BS&W, densitometers, pumps, and pump controls. All systems should be fully-tested at the manufacturer's facilities prior to shipment. This would include a hydrostatic test, as well as a full-flow test with the control console. Documentation should include "as-built" drawings, all instrumentation and calibration certificates, and operating manuals for each piece of equipment in the system.

Conclusion

As seen above, the design of liquid measurement systems is affected by a number of different factors. What is of key importance to one user may be a secondary issue to another user. Even on systems with similar flow rates, the number and sizes of meter runs may differ. It is extremely important in the specification stage and early in the design stage to completely understand the alternatives and how they will affect the system design and the overall performance of the measurement system. With this understanding in hand, you should have the ability and knowledge to design a system ideally suited to meet your specific requirements.

Acknowledgement

This paper was originally presented by the author at the International School of Hydrocarbon Measurement (ISHM) at the University of Oklahoma on May 21-23, 1991.

The specifications contained herein are subject to change without notice and any user of said specifications should verify from the manufacturer that the specifications are currently in effect. Otherwise, the manufacturer assumes no responsibility for the use of specifications which may have been changed and are no longer in effect.

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