LIQUID MEASUREMENT STATION DESIGN
Class No. 2230.1

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INTRODUCTION

The industry continues to benefit from advancements in metering technologies, instrumentation and computer control systems applied to liquid measurement equipment. These advancements result in increasingly complex and sophisticated requirements for interfacing with the mechanical equipment. Complete compatibility of the instrumentation system with the metering components must be incorporated in the design to assure optimum functionality of the system.

This paper outlines design considerations and other factors that should be considered in specification and construction of flow measurement stations for hydrocarbon liquids.

APPLICATIONS

Liquid measurement stations are utilized in a variety of applications including metering of crude oil, refined products, NGL, LNG, and chemicals. Station configurations vary from single meter run applications with manual valves and connections for a temporary meter prover to stations handling several liquids with multiple meter runs for each product with an on-line prover dedicated to each liquid.

Pipeline applications include measurement at pump stations feeding pipelines, outlet terminal metering where distribution is made to multiple users, and metering at additional inlet locations on the pipeline. The various products are segregated during transportation by utilizing pipeline pigs to separate the liquids, which allows continuous metering and serves to reduce tankage requirements.

Metering at marine tanker loading or unloading facilities is another application for liquid measurement stations. Flow measurement may be either to or from a pipeline, a production and storage facility, a refinery, or a petrochemical plant. Offshore facilities offer unique design challenges for metering units because of limited available space. Where feasible, a Floating Production, Storage and Offloading unit (FPSO) may be utilized to provide early production of crude oil, by moving an existing vessel to the oil field. A meter station installed on the tanker will provide measurement for both storage and offloading to a transport vessel. Another common application is measurement of liquids pumped into or from underground storage caverns or salt domes.

Most liquid products are measured at or near ambient or underground pipeline temperatures. However, increased demand for transportation of products such as butane, propane, and LNG has required meter stations to be designed for refrigerated or even cryogenic temperatures.

The metering applications noted above have traditionally utilized turbine meters or positive displacement meters for custody transfer measurement. Liquid ultrasonic meters and Coriolis meters are the emerging technologies to the liquid custody transfer marketplace. The selection of the type of meter depends upon the properties of the liquid to be measured, primarily the range of viscosity to be handled.

A measurement station could be designed for either field construction or fabrication in a shop facility. Fabrication and assembly of the system in a facility which specializes in measurement systems will lower field construction costs and shorten the project schedule A pre-checked station offers the assurance of a working system prior to final field commissioning. When constructing new facilities in remote locations, there is a significant economic factor in favor of pre-assembled metering systems.

ARRANGEMENT

A typical flow diagram for a pipeline metering system is shown in Figure 1. This diagram indicates a station comprised of four (4) meters, arranged for parallel flow. A common inlet header distributes flow to each meter run. Selection of sizes and quantity of meters is based on careful consideration of maximum and minimum station flow rates required, combined with economic factors. Figure 1 indicates a common outlet point; although the number of inlets and outlets would be determined by requirements of the specific installation. In the case of multiple connections, the meters could be grouped, with each bank of meters arranged for a specific flow path; or the meter lines may be provided with manifolds to allow any meter to flow to any connection point selected by valve interlocks. The following sections provide design information to be considered for individual components in the system.

INLET BLOCK VALVES

Block valves at the inlet to each meter section enable isolation of the meter section for maintenance purposes without interrupting flow of the entire station. A spare meter line is sometimes provided in the station to maintain full station flow rate capacity while allowing maintenance of one line. The inlet valve is usually a gate valve; double block and bleed type valves are not needed in this location, unless there is a concern for small amounts of leakage during maintenance.

STRAINERS

The purpose of the strainer at the inlet to each meter section is to screen out material carried by the liquid, which would damage the meter. A differential pressure instrument on the strainer signals excessive pressure drop due to plugging of the strainer basket, thereby alarming the operator to clean the screen or basket. The strainer body, which is a high point in the piping system upstream of the meter, provides a good location for an air eliminator to vent air or gas during startup and operation. Any air or gas in the liquid will affect the volume measured by the meter. The strainer helps to separate air from the liquid due to reduction in fluid velocity as the liquid passes through the strainer.

METERS

The primary measuring instrument is the heart of the measurement system. For optimum performance the meter must be capable of covering a wide flow range over which the meter maintains a linear pulse output with respect to flow rate; typically, ±0.25% for a 10:1 flow range. The meter could be a turbine meter, a positive displacement meter, an ultrasonic meter or a Coriolis meter. A turbine meter and ultrasonic meter offers the advantages of availability in higher flow capacities and savings in weight, space and maintenance. Utilization of both the turbine meter and ultrasonic meter requires installation of straight sections of pipe upstream and downstream of the meter to condition the velocity profile of the liquid stream. Flow straightening tube bundles or conditioning plates are normally included in the upstream meter tube. Positive displacement meters and Coriolis meters do not require upstream or downstream flow conditioning. The API Manual of Petroleum Measurement Standards provides the guidelines for meter installations.

FLOW CONTROL VALVES

Flow control valves are used in multiple meter installations to equalize flow in all meters, where an imbalance might otherwise exist. Maximum throughput is thereby realized by operating each meter near its maximum capacity. Flow control valves are also used during meter proving to maintain the flow at the same rate at which the meter normally flows. In addition, flow control valves provide the means to operate each meter at various flow rates over its characteristic curve.

The flow control valve location shown in the diagram provides optimum control for all metering applications, while avoiding problems associated with location of a flow control valve between the meter and the prover. The indicated arrangement will result in better flow control and minimize the difference in fluid conditions between the meter and the prover. Optimum proving results are obtained when the meter prover operates as close as possible to the metering conditions.

Flow control valves should be designed to close against the maximum upstream pressure that will occur, with no pressure downstream, in order to avoid damage when the valve operates against full differential pressure.

Careful evaluation should be given to the desired action of the flow control valve upon loss of either its control signal or actuator power. The valve may be designed to open, close or remain in its current position.

DOWNSTREAM BLOCK VALVES

A valve at the outlet of each meter section (downstream of the flow control valve) is used to establish flow through the meter selected and to block flow when so desired. A valve connecting each meter section (upstream of the flow control valve) to the prover inlet manifold is used to divert flow from the selected meter to the prover. Flow is thus routed to the prover by opening the prover block valve, then closing the downstream meter block valve to minimize pressure surges and flow variations in the system.

To assure accuracy of metering and proving, the downstream and prover block valves must be of a high reliability, double block and bleed design. Due to the high frequency of operation of these valves in multiple meter systems, the ability of the valves to maintain bubble tight shut-off over the long term is extremely important, as a small leakage will cause measurement errors. These valves should be supplied with a means to verify seal integrity.

PROVER

The mechanical displacement meter prover provides the means for calibration of each meter to a known volumetric standard. This is accomplished by displacing a volume of liquid between two points (switches) by a mechanical displacer inside the prover pipe while the meter signal is being recorded. The volume between switches is precalibrated by the waterdraw method using calibrated test measures certified and traceable to the National Institute of Standards. An on site prover allows continuous flow through the meter being calibrated, with the liquid at its actual flowing conditions, without the need to start or stop the flow. It is desirable to have a permanently installed prover to allow frequent calibration of the meters in order to maintain long-term accuracy.

A bi-directional prover is indicated in Figure 1, although bi-directional, uni-directional and compact prover types are commonly used. Due to the high usage frequency in calibrating meters, it is important that the prover and associated equipment be constructed for high reliability.

FOUR-WAY VALVE

The four-way valve diverts the flow in either direction through a bi-directional prover loop. For a uni-directional prover, a sphere interchange and seal assembly is used instead of a four-way valve due to the different principal of operation of the prover. In either case, high reliability performance is necessary, and a device for checking the valve or interchange seal integrity is recommended. The diagram shows a differential pressure indicator/switch for this purpose.

DETECTOR SWITCHES

The sphere inside the prover pipe, or the piston in a piston type prover, actuates detector switches mounted on the prover loop. The switches start and stop a digital counter in the instrumentation connected to the meter being proved. The resulting meter pulse count, temperature and pressure correction factors and prover base volume data are used to determine the meter factor for each meter.

INSTRUMENTATION

Pressure and temperature instruments located downstream of each meter and on the prover provide readings used to make corrections for volumetric changes of the liquid due to pressure and temperature effects. If measurement results are to be expressed in mass units instead of volume, an instrument is provided in the system for direct measurement of fluid density. Depending upon the extent of remote operation desired, pressures, temperatures, valve control and status, and other information is transmitted to and controlled from an automated instrumentation panel located remotely from the meter station. The software system is designed to automate the system control functions, provide data logging and perform calculations for liquid measurement.

Typically, the flow measurement parameters of each metered stream are logged by a Stream Flow Computer (SFC), which calculates liquid volume corrected to standard temperature and pressure conditions. In a multiple meter run system, the same signals are fed to a Station Supervisory Computer (SSC), which provides total station flow data, controls valve positions, and indicates status and alarms.

Operator interfacing (HMI) utilizes a CRT display, keyboard, mouse and printer. The Graphical User Interface (GUI) displays include graphics diagrams of the metering system in addition to operating data such as flow rates, temperatures and pressures.

MECHANICAL DESIGN

Arrangement of piping and equipment in a metering system should allow suitable access for operation and maintenance of equipment, while minimizing space requirements. Piping manifold and header design is important to the liquid flow pattern in the station. Proper sizing and arrangement will provide better balance of flow between meter tubes without sacrifice due to excessive pressure drop. Manifold or header liquid velocity should not exceed 15 feet/second for best flow distribution and lower pressure drop. Valve sizing is also important in regard to pressure drop. Block valve sizes are usually one pipe size larger than the meter for turbine meter applications, and the same size as the meter for positive displacement meter applications.

Features that are included in the station to improve operation and maintenance include quick opening closures on strainers and prover launch chambers, and jackscrews and spacer plates in the meter section to facilitate removal of meters. A jib, monorail or bridge crane is often included to aid in strainer basket removal, valve maintenance or sphere installation and removal.

In liquid systems, a pressure relief valve should always be included in each section of pipe that might be blocked off while filled with liquid. The relief valve will protect piping and equipment from being over pressured by liquid expansion due to solar heating.

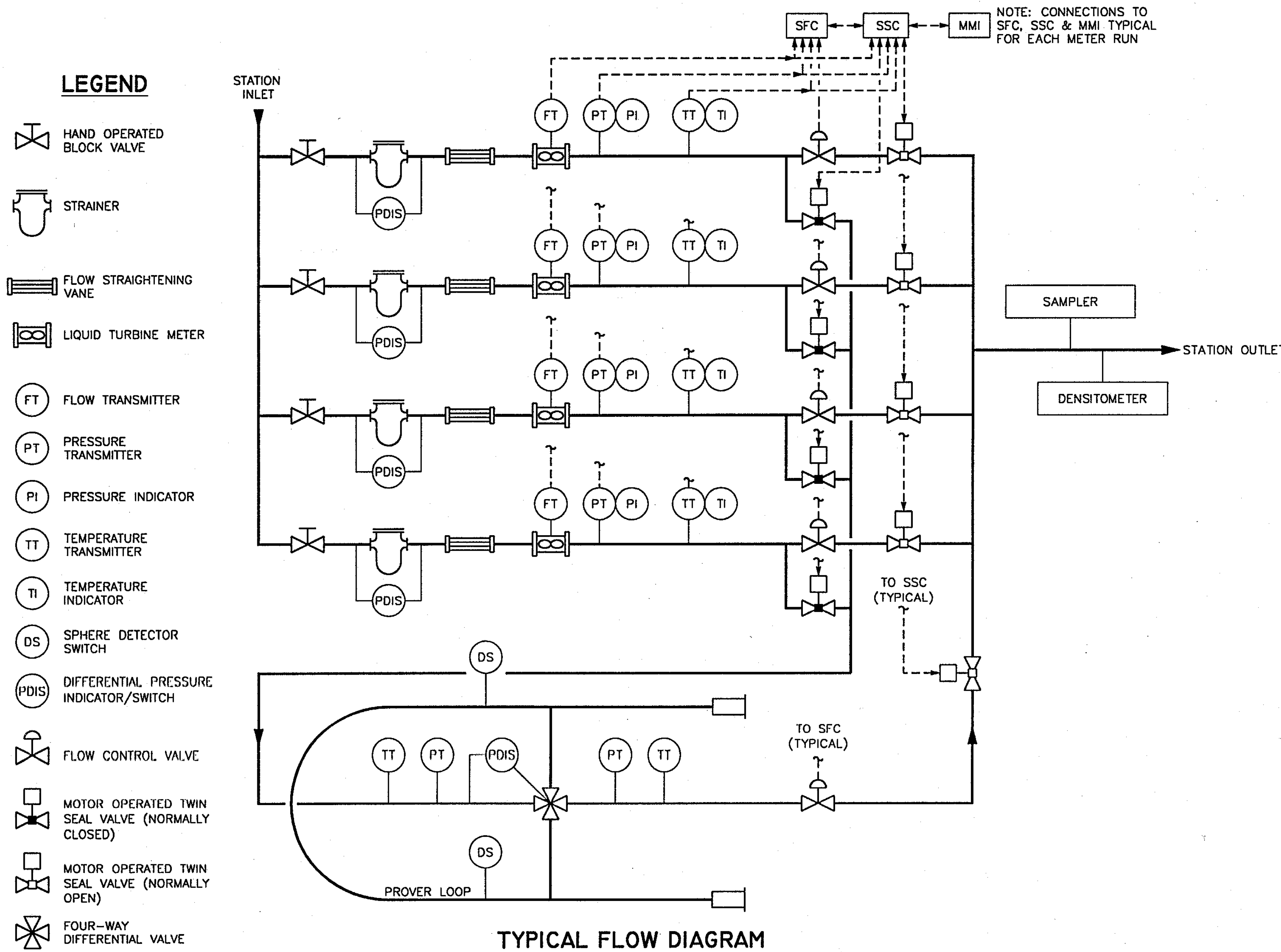
If densitometers, samplers, BS&W monitors or other instrumentation is included in the system, they should be connected so as to provide the best possible representative measurement sample for all meter sections.

Modular design of a liquid measurement system offers a significant economic advantage over a field-constructed system. Structural steel skid frames may be used to support the pre-fabricated piping and instrumentation system. Electrical wiring of all devices to terminal strips in local mounted junction boxes minimizes site installation time. System functionality, complete with remote instrumentation and software, may be verified in a controlled environment rather than in the field.

The units are then easily transported to the field, where tie-in of piping connections and wiring between the remote panel and the local junction boxes is completed. Installation of a pre-checked unit ensures that all components are compatible and that the system is in optimum working condition prior to filling it with product and commissioning the measurement system at the site.

CONCLUSION

Design of liquid measurement stations must include careful evaluation and selection of all components that affect the transfer units of measurement, either volumetric or mass. By minimizing the measurement uncertainty for each parameter that affects liquid measurement, such as operating temperature or pressure, the overall system uncertainty is reduced. In addition, proper operation of the metering and proving systems, combined with periodic maintenance and calibration of devices that affect flow measurement will result in optimum performance of the system.



TYPICAL FLOW DIAGRAM
LIQUID METERING AND PROVING SYSTEM