Title: High Capacity Liquid Measurement Systems by Drew Weaver

HIGH CAPACITY LIQUID MEASUREMENT SYSTEMS

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INTRODUCTION

The large scale demand and increased costs for crude oil and refined products have continued to increase the need for high capacity liquid measurement systems. The accuracy of the measurement system is of prime importance due to the large volumes being transported. For instance, as 48" pipeline such as the Alaska Pipeline has a capacity of approximately 1.7 million barrels per day. At today's crude oil price of approximately $30.00 per barrel, this flow represents over $50 million/day. On the other hand, a supertanker of crude at a capacity of approximately 3.5 million barrels represents a cargo value of over $100 million. With such large monetary values, reduction of flow measurement errors is of paramount importance. "High Capacity" would be difficult to define in terms of flow rate, as the amount had always been increasing. However, for purposes of discussion, "high capacity" in terms of metering to a single point would mean a flow rate in the range of approximately 20,000 BPH to 200,000 BPH. This paper discusses current method of large volume liquid flow measurement and offers the designer or user some general guidelines in regard to arrangement and specification of equipment.

APPLICATIONS

Pipeline terminal metering is a major application of large measurement systems. Depending on the pipeline system, metering may be installed at either end of the line and outlet points along the line. Through the use of continuous metering, tankage requirements are reduced. Several products may be transported by use of pigs or spheres which separate and prevent mixing of products and allow continuous metering.

Tanker loading and unloading is another major use of large measurement systems. Depending on the facilities of the port, metering may be located onshore or on an offshore platform or "sea island". Metering systems have also been installed on tankers, which are used for combination storage and loading terminals. Oilfield production and storage platforms are another application of metering facilities.

A fourth application has for metering crude oil or products into or from underground caverns or salt domes for storage purposes.

Applications such as these may utilize either turbine meters or positive displacement meters, but this paper will concentrate primarily on turbine matters due to their advantages in application to large liquid flow measurement systems.

CODES AND STANDARDS

The API Manual of Petroleum Measurement Standards is the basic guide for design and operation of measurement systems. The following chapters are of importance in regard to metering and proving applications:

- Chapter 4, Proving System
- Chapter 5, Section 2. Measurement of Liquid Hydrocarbons by Displacement Meter Systems
- Chapter 5, Section 3. Turbine Meters

The API standards, of course, do not "tell you all you need to know" about flow measurement systems, but do serve as accepted standards in this field and are usually referred to in specifications for metering systems.

In addition to the above measurement standards, meter systems must be designed and constructed according to the applicable piping, structural steel, materials, and welding codes and standards. Typical piping codes are ANSI B31.4 for liquid transportation piping and ANSI B31.3 for petroleum refinery piping. The American Institute of Steel Construction usually covers structural requirements.

ARRANGEMENT

A typical turbine meter station and prover arrangement is shown in Figure 1. For simplicity, this diagram indicates a bank of four (4) meters, although many large stations would consist of more meters than four. Also, only one inlet and one outlet is shown, whereas multiple inlet or outlet manifolds and valving may be provided to accommodate more than one inlet and to provide distribution of flow to several loading berths or similar points. For multiple connections, the meters may either be arranged in banks which serve one flow arrangement or complete flexibility may be provided such that any combination of meters may be set up to flow to any of the outlets. A bi-directional prover is shown, although a uni-directional prover could be used instead.

COMPONENTS

INPUT BLOCK VALVES

A block valve to provided at the inlet of each meter run for the purpose of isolating the meter section for maintenance purposes without requiring shutdown of the entire station. This valve is typically at gate valve or ball valve. A block and bleed arrangement way be required on the valve where there is a concern for leakage of light products such as propane or butane during removal of the meter or meter section. An electric or hydraulic actuators usually provided because the size of the valve or quality of valves results in manual operation being undesirable.

STRAINERS

The purpose of the strainer is to screen out material carried by the liquid, which may damage the meter. For large turbine meters, 2 X 2 wire mesh or equivalent is adequate. A differential pressure indicator/switch in useful in signaling when the strainer becomes plugged up and needs cleaning.

AIR ELIMINATORS

An automatic air eliminator may be provided to remove slugs of air present in the liquid, such as during startup of the system. The strainer top is a good location for the air eliminator, since it is a high point and the strainer provides some reduction of velocity as the liquid flows through it. Small quantities of air will not damage the meter, but will cause inaccuracy in liquid volume measurement.

UPSTREAM METER TUBES

A straight section of pipe is used to condition the velocity profile of the flow stream ahead of the meter. The length of this tube is determined according to API standards. If a straightening vane bundle is included. The required length of straight pipe is less than if the vane were not used. On large size meter tubes, the space savings of using vanes is significant.

METERS

The primary measuring element may be either a positive displacement meter or turbine meter. However, the turbine meter has the advantage of availability in higher flow rates and offers savings in weight and space requirements. The meter must have a wide rangeability in terms of flow rate and must have good linearity over the flow range. Typical turbine meters tested on water have a linearity within +0.25% over a flow range of approximately 10 to 1. Repeatability, or the ability of the meter to provide the same output at some later time as the original output under the same conditions, is also important. Typical turbine meters are repeatable to within +0.02% at any particular flow rate within the range of the meter.

DOWNSTREAM METER TUBES

This section consists of a straight section of pipes to condition flow downstream of the water. The required length of this is always shorter than that upstream section.

PRESSURE INSTRUMENTS (METER SECTION)

An instrument for reading the line pressure is usually installed immediately downstream of the meter tube. This reading is used in proving calculations. An electronic transmitter is normally used on large installations and whenever a remote panel is provided. A gage installed for local observation of pressure.

TEMPERATURE INSTRUMENTS (METER SECTION)

Similarly, an instrument for reading fluid temperature is usually installed downstream of the pressure instrument tap. An electronic transmitter is used to provide a signal for remote indication, whereas a test well is normally included for manual checking of temperature with a laboratory type thermometer. The reading is used for proving calculations.

FLOW CONTROL VALVES (METER SECTION)

It is important to have flow control valves for several reasons. In a large installation of many meters, the control valve may be used to trim flow rates for equalization of flow in all meters where an imbalance may otherwise exist. Secondly, when the flow for one meter is diverted through the prover, the flow rate for the meter being proved will be reduced due to the additional piping and valving in this flow path. The flow control valves are used to throttle the flow through the remaining meters in order to increase the flow through the meter being proved back to normal. Thirdly, operation at reduced flow rates is desired in many instances, such as for startup or for topping off at the end of a tanker loading. Many types of valves are available for flow control applications, and each application should be investigated thoroughly in regard to section of a valve and control system.

DOWNSTREAM AND PROVER BLOCK VALVES

These valves are used to establish the flow path of the liquid Ieaving the metering section. Normally, the prover block valve is closed and the upstream and downstream block valves are open, resulting in flow directly to the outlet header. For proving a meter, the associated prover valve is opened and the downstream block valve is closed, diverting flow through the prover and back to the outlet header.

To insure accuracy of metering and proving, these valves must be of a high reliability block and blued design. Due to the high frequency of operation of these valves on large systems, ability to maintain bubble tight shut-off over a long period of time is of utmost importance, as small leakage's can give erroneous results. Electric or hydraulic actuators are usually provided for these valves because of valve size, frequency of operation, and remote control requirements.

PROVER

The prover provides a means to calibrate the meter by displacement of a known volume of liquid between two points by a mechanical displacer. This calibration method allows continuous flow through the meter being calibrated, without starting or stopping. The need for the prover is based on the desirability to provide periodic calibration of meters in order to maintain long term accuracy. On many large systems, the meters are proved many times per day. The prover and associated valving is another area where high reliability is very important.

FOUR-WAY VALVE

The four-way valve is the means by which the flow is diverted in either direction through the power loop of a bi-directional prover. For large provers, this valve is normally provided with an electric actuator or a hydraulic actuator on the very large provers due to the power and speed of operation required. A differential pressure indicator/switch is provided to signal the valve seal integrity during operation of its prover.

DETECTOR SWITCHES

These switches are actuated by the displacer, which is usually an inflatable sphere made of an elastomer material. The detector switches gate the prover counter during proving or calibration runs.

PRESSURE AND TEMPERATURE INSTRUMENTS (PROVER)

Instruments similar to those provided for the meter tubes are installed on the prover inlet and outlet to read fluid temperature and pressure. These readings are used for establishing correction factors during proving a meter.

PROVER FLOW CONTROL VALVE

A control valve similar to that provided in the meter tubes is located at the prover outlet. This valve is used to throttle flow for proving of meters over the entire flow range.

PROVER ISOLATION VALVES

These valves are for the purpose of blocking off the prover for maintenance work without shutting down the meter station. The inlet isolation valve is optional, depending upon the metering arrangement and the distance of the prover from the meter station.

REMOTE INSTRUMENTATION

Many functions may be controlled and indicated by the remote panels and computer system. On large systems using a computer, normal operational control and logging is through the computer. The instrument panel is used for manual control back up, indication, and permanent recording of data. A graphic panel is usually provided for valve control and status information. A valve interlock system may be provided to insure proper operation sequencing of valves. An enunciator panel signals alarms such as high differential pressure on strainers, high or low flow rates, etc.

Panel mounted flow rate indicators and totalizers register output from the meters. Adders sum the flow of all meters. Panel mounted strip chart recorders provide continuous record of temperatures and pressures. Digital meters indicate meters indicate instantaneous pressures and temperatures. A prover counter registers meter pulses during proving.

Operation through the computer to by means of the keyboard and CRT display combination. All data is fed into the computer from the instrument panels through suitable interfacing. Software programs may provide automatic sequencing of valves to establish flow through a meter run, automatic proving operation, flow control, and metering and proving calculations. CRT displays or printouts of calculated results and status information may also be provided, in addition to the normal delivery tickets usually printed by a separate panel mounted printer.

DESIGN CONSIDERATIONS

Selection of valve sizes to an important consideration in design of the system. Valve CV fracture should be closely investigated in relation to normal operating and maximum design flow rates. If continuos operation at the maximum linear flow rate of the turbine meter is desired, block valves will normally be one nominal pipe size larger than the meter. Flow control valve operation should be considered in regard to pressure drop at maximum flow rate, shutoff pressure drop required, cavitation or flashing when throttling, signal failure mode, and response time.

Overall system pressure drop may be important for large systems. At a flow rate of 200,000 BPH. a reduction of 1 PSI in overall pressure drop results in a savings of approximately 96 HP pumping cost. This saving would be equivalent to about $17,500 per year at a power cost of $0.03 per KWH. It would be worthwhile to consider some additional capital expenditure in piping and valving for reduction of pressure drop. However, there are limitations due to velocity requirements for the turbine meter.

Another consideration is that the backpressure immediately downstream of the turbine meter should be above the minimum requirement in order to prevent cavitation.

One aspect of design that might be overlooked is that installation of the measurement system should be such that the system will remain filled with fluid between operations if there is alternating startup and shutdown such as tanker loading or unloading. By keeping the system filled, start-up will be much simpler and accuracy will be improved.

Modular skid construction is significant economic factor in design of large measurement systems. The system can be assembled, hydro-tested, wired, checked out, and functionally tested together with the remote instrumentation in the shop. After completion of testing, the equipment is unflanged between skids, which separates the system into units suitable for transport to the field. This method of construction minimizes the amount of field construction a assures a working system prior to being shipped to the final location.

Arrangement of the system piping should be considered in regard to access and maintenance requirements in addition to pressure drop and flow measurement aspects. An example in this regard is design of headers or manifolds. An arrangement which maintains the best balance of flows between meter tubes should be considered. Manifolds on large systems usually span the width of several skids. The skids may be transported to the field by removing the entire header if flanges are not provided between skids. However, if the overall situation is analyzed in regard to additional field assembly to reconnect the header to the meter runs, adding a few sets of flanges in the header may result in an overall savings. There would then be fewer connections to make in the field.

Large meter tube sections should always have a spacer plate and a set of flange jackscrews installed to facilitate removal and installation of the turbine meter for maintenance.

Quick opening closures on strainers and prover launch chambers facilitate removal and cleaning of strainer baskets and removal of the prover spheres.

Relief valves for protection from over-pressuring piping due to expansion of liquid from solar heating are necessary where a section of piping may be blocked in by closing valves.

Additional instruments such as temperature and pressure transmitters, densitometers, and samplers may be located on inlet or outlet headers. It is important that these instruments be located so as to represent a measurement sample from all meter sections, with consideration of the fact that some of the meter tubes will not be flowing all the time.

Insulation of piping downstream of each meter up to the prover and the prover loop is recommended to ensure that the temperature in the prover is as close as possible to the temperature at the factor and eliminates effects of unknowns which might result in inaccuracy.

Remote instrumentation should be considered carefully in regard to the desired operational control and indication requirements.

SUMMARY

High capacity flow measurement systems are comprised of many individual components, which serve various functions, resulting in a complex working arrangement. A flow measurement system may be designed to the individuals needs of the user. Design of the system involves consideration of the relationship of each piece of equipment to the other, while keeping foremost in mind those factors, which contribute to the best overall flow measurement.