Title: High Capacity Liquid Measurement Systems by Paul J. LaNasa

HIGH CAPACITY LIQUID MEASUREMENT SYSTEMS

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Most of us are at least somewhat familiar with the size of battleships and aircraft carriers which are in the 100,000 DWT size. Perhaps you remember when the 115,000 DWT ice breaker-tanker "Manhattan" made its historic trip to Prudhoe Bay by way of the Northwest Passage. It didn't load much North Slope oil on that trip back to the United States, but we think of the "Manhattan" and of the war ships as big vessels.

Now, about every four to six weeks, certain oil loading terminals in the Middle East are visited by either the "London Galactic" or the "Tokyo Galactic": tankers in the 477,000 DWT class. These 3.5 million barrel supertankers (proper name classification being Very Large Crude Carriers-VLCC) must be loaded in as short a time as possible to make their use economical. They don't have much of a payout while tied up to a loading berth. This, then, is the incentive to use high capacity metering systems in this particular area of the world.

Major pipeline systems here in the United States have been using large meter systems for some years now in both crude oil and finished product services.

Plantation Pipeline, Colonial Pipeline and Explorer Pipeline systems are examples of big product lines which use meters for measurement. Capline, Ozark, and Ranch crude systems use meters in many terminals.

In all of these systems the concept of continuous flow through meters rather than the batch operation of tank measurement has allowed a more efficient usage of the operations people involved while reducing the probable human intervention in measurement.

Obviously, new problems have been created for the structural design engineers who are responsible for the design and construction of platforms and sea islands for loading supertankers. Conservation of space and weight limitations are major considerations. This has dictated the use of turbine meters for these applications.

Turbine meters of the 16", 18" and 20" diameter sizes are commonly found in these loading terminals throughout the Middle East. Twenty-inch (20") meters are capable of flowing and accurately measuring up to a rate of 42,000 barrels per hour per meter. A bank of four 20" meters will operate at better than 160,000 barrels per hour flow rate through an automated system to load a supertanker in something under 24-hours. It is also apparent that, for custody transfer quality measurement (which is the type of measurement that is involved in these instances), accurate and reliable equipment of all types is required.

Custody transfer is a term we use primarily here in the United States to transfer ownership of responsibility for custody of a measured volume of fluid. In other parts of the world, they may use other terms meaning essentially the same thing (such as royalty measurement, fiscalization or meters for tax determination).

In any case, the main measuring element (in this case, the turbine meter) is required to have a good linear curve over a wide flow range. To calibrate these meters, a prover system is required, and along with all of this are the manifolds, valves, strainers, meter tubes with straightening vane sections, transducers, interlock systems, etc. More than just fundamental pulse proving is required for the registration during the loading period; corrections for temperature, pressure and gravity changes must usually be made. Built-in alarms systems are designed into the system to substantiate the reliability of its operation.

The system must also be versatile. It must be capable of accurate measurement during periods of low rates for start-up and topping off, and it must be capable of long time accurate measurement at high flow rates for the loading process of the vessel. Generally, it must be able to present a log of total flow, temperature, pressure and gravity for the oil accounting measurement people at the end of the loading.

To assist the engineers, designers, as well as the owners and operators of such equipment, the American Petroleum Institute has published several standards which are used as guidelines in the design, installation, calibration and operation of turbine meter systems. Almost every set of specifications for a turbine meter system contains the words "and the system shall conform to API Standards 1101, 2531 and 2534." While there are not hard and fast rules and regulations in these standards, there are general guidelines which most design as well as operating companies use to a great convenience. These standards are presently being updated to reflect new innovations in equipment as well as later concepts of measurement theory that have evolved since the original publication.

Figure 1 is a photograph of a relatively standard system. The metering unit consists of three 10" turbine meters, and the prover is a 30" bi-directional prover. Flow enters from the left side of the photograph into an inlet header, through the inlet valves and through the strainers. Immediately downstream of the strainers are the meter tubes with straightening vane sections, a necessary requirement for good measurement in a turbine meter system. Next are the turbine meters. Flow then enters into the insulated piping section which proceeds downstream to the discharge header. Normal flow is in this pattern: in the inlet header, through the valve, strainers, meter tube, meter, discharge valves, and out the discharge header; however, when the meter is to be calibrated, the prover shown on the right hand side of the picture comes to play. The flow is diverted to one of the upturned insulated ells through a valve while the discharge valve is blocked off. Flow through the upper insulated section then moves over to the prover through the four-way valve and the prover and back into the discharge piping of the meter system. This unit (with three 10" turbine meters) is capable of measuring up to 33,000 barrels per hour of light hydrocarbon fluid. The discharge header valves, the prover header valves and the prover four-way diverter valves are all electro-hydraulically operated and can be remotely operated from a control panel in the instrument control room. The output signal from the turbine meter is sent through shielded cables to the temperature compensated totalizer, which is in the same instrument cabinet in the control room. Flow may be through any one or all of the meter tubes, therefore providing a total rangeability on the system from a minimum of about 900 barrels an hour (single meter flow rate) to a maximum of something over 33,000 barrels per hour.

Earlier in the paper, mention was made for the need of conservation of space on the loading platforms upon which the meter units are placed. Figure 2 is a photograph of a unit in operation in the North Sea that is located on the cellar deck of a production platform. This unit is essentially two separate metering systems with a common prover shared between them. Each metering system has three 10" meters complete with 10" inlet and outlet valves, but also has crossover connections so that both sections can be tied together to either load from a common stream or discharge to a common stream header. This is a very compact unit and fits into a space approximately 38-feet long by 38-feet wide and 12-feet high. It has a total measurement capacity of 66,000 barrels per hour. All valves are electro-hydraulically operated and remotely controlled from a central control panel. Again, the piping from the discharge end of the turbine meter through the discharge header and over through the prover system is insulated. This is to maintain the same temperature throughout the prover system and the discharge header system as is measured by the turbine meter system. The insulation provides assurance that, when the meter is being proved, the temperature of the flowing fluid as sensed by the meter is the same as in the prover. Flow control valves are located downstream of the turbine meter to regulate the flow through the meter during several different periods of operation.

These flow control valves play dual roles in the operational scheme. First of all, when one of the three meters in the group is being proved, that meter (when valved into the prover piping system) will experience a slightly greater pressure drop loss through this longer piping connection. This will cause the flow rate to that meter to drop off slightly. To bring that meter back up to normal flow rate, the other two-meter streams are throttled sufficiently to produce a pressure drop across the throttle valves equal to the additional pressure drop in the prover piping of the meter being proved. These flow control valves are also used during the final top off stages in loading a tanker when the flow stream is reduced down from something near the normal maximum to a minimum flow. The unit has pressure, temperature and gravity transducers on it, with all signals being fed through the cables to the junction boxes. From there the signals go into the control room where, as we see on Figure 3, the instrumentation panel is located. Primary control for this flow metering station is through a digital process computer with input-output through a Teletype device as shown in the photograph. The operator communicates to the system by means of the Teletype keyboard and directs the unit to load the desired quantity at the selected flow rate. For operational visual display and emergency manual back up, the other instruments and mimic panels come into use. Mimic panels show by lighted push-button switches the position of valves in the meter and prover manifolds, and the totalizers in the center instrument panel section are used as back-up totalizers for registration of the meter throughout. Also included is a prover pulse counter, as well as temperature and pressure recorders.

Basic control of the system is through the digital process controller. The computer has sufficient core memory and has been programmed to handle all normal tanker loading control functions, including start-up and topping off with flow control. Working currently with this is the program, which monitors for safe operational control of the system and provides alarms and printouts of any alarm conditions. Another program directs automatic proving of the turbine meters if this function is desired and requested by the operator. Periodic status reports are developed and, at the end of the load-ing, final quantity calculations are made for billing.

Figures 4 and 5 are of another large meter-prover unit, which is in operation in the Arabian Gulf area. The meter unit consists of ten 20" turbine meters, each with a maximum capacity of 42,100 barrels per hour, giving the unit a total capacity of 421,000 barrels per hour. A unique feature of these units is the fact that they were built in modular construction on four separate skid units which flanged and bolted together very easily at the job site. The photograph shows the units as assembled at the factory for tests in a complete assembled appearance. When the tests were completed, the units were unflanged to allow packing and crating of the modular sections. They were shipped to the location site where they were quickly and easily reassembled.

It can also be seen from Figure 5 that the instrumentation panel in this unit is more elaborate and detailed. Here again, the computer is the primary control function for the system, but is was desired to have a more detailed visual display of instru-mentation as back-up information.

While up to this point this paper has been concerned with the loading of tankers through turbine meter systems, the reverse process of unloading is also upon us here in the United States. The problems of loading have been associated with the other growth problems in the large crude oil pro-ducing areas -- large valves, pumps, sub-sea structures, etc. Now, a new set of design criteria is being generated for the large unloading facilities, which will be found in the United States port areas. At present, there are two groups working in the United States toward designs for large tanker unloading facilities in the Gulf Coast area: the Sea Dock Group and the LOOP Project.

There is another method of measuring and storing crude oil from a production field, which is rather unique and might be worth a few words of discussion here. In two areas of the world, rather large storage tankers or barges are anchored semi-per-manently in the sea near the production area. The production platforms are complete with separators and treaters so that their output is custody transfer quality oil. This oil is then fed to the storage vessel through a loading line and is measured for inventory purposes through smaller turbine meter units into the cargo tanks. The crude continuously flows into the hold of the ship where it is stored until sufficient storage is available to unload and fill or top off another scheduled tanker, which will transport the crude to a refinery area. The load is transferred, using the cargo pumps, forcing the oil through the meter unit, over the side of the vessel through a large pipeline to a single buoy mooring point. The transporting tanker is attached to the SBM by means of a very large diameter hose connection. In essence, this floating barge or tanker is nothing more than a floating storage tank (with pumps), since there are no facilities for oil treatment or handling other than just the routing storage requirements.

It may be a few years before we will see such super mammoths entering our local port areas, but with the energy "squeeze" upon us, it is certainly a fact that the era of the supertanker is here and ready to unload at our terminals. We need to prepare in all aspects of tankage, pumps, pipelines, structures, as well as measurement capability.