LPG PIPELINE METERING

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ABSTRACT

LPG's are classified as any hydrocarbon liquid having a vapor pressure greater than atmospheric. Under minimal pressures, LPG's can be held in the liquid state, which simplifies storage, transporting and measuring. When pressure is released, LPG's readily vaporize making them an ideal energy source for fuel when the vapor is ignited.

The safest and most accurate method of transferring LPG from a bulk storage facility to a pipeline is through a reliable metering system. The basic concept in designing an LPG Metering System is to provide dependable components, which can safely be operated by trained personnel.

In the case of a pipeline installation, the system must be designed to provide unattended operation with a minimum amount of maintenance. A transport loading system must provide a means to limit the filling of the transport and provide a hard-copy of the total volume and the amount of odorant injected for each loading transaction.

Basic equipment selection and design considerations should include the following:

DESIGN CODES

The thorough review and understanding of Design Codes and Safety Standards are the first steps in planning a successful installation. Design Codes may vary slightly from country to country and state to state. Most states and South American Countries adopt United States National Codes and guidelines such as the Department of Transportation (DOT) covering transportation regulations, the American National Standards Institute (ANSI) covering pipeline and refinery locations, the American Petroleum Institute (API) covering custody transfer metering and proving and the National Fire Protection Agency (NFPA) covering safety design considerations.

DESIGN CONSIDERATIONS

LPG's are much more sensitive to pressure and temperature than crude oils due to their high vapor pressure, their high compressibility and their low density. Temperature and pressure can impose a high degree of error on the high vapor pressure products such as the LPG's. In the case of propane, a 10% error in temperature could effect measurement by 1.4%, while a10% error in pressure could effect measurement by 0.3%. Due to these characteristics, precise measurement of temperature, pressure and density are an absolute requirement for accurate measurement.

Measurement can be determined using either volumetric or mass calculation methods. Volumetric measurement uses a meter (turbine or positive displacement) to count the “gross” number of volume units through the meter. The gross volume is corrected for pressure and temperature to obtain a corrected “net” volume based on a standard of 60 degrees F and 14.7 PSIA. Mass measurement uses a meter (coriolis) to measure the volume and density passing through the meter to determine total mass. Because the mass of a liquid is the quantity of matter it contains, it is not affected by temperature, pressure, buoyancy or acceleration. Mass is mass, no matter what the operating conditions may be.

In instances where an LPG contains a high ethane content, a measurement error could occur using volumetric measurement. This is due to solution mixing, which allows smaller molecules in a product stream to hide within the voids between larger molecules. Mass measurement would eliminate this error.

Accurate metering alone will not assure accurate measurement. Sampling and analysis is equally important. Two acceptable methods of analysis include composite sampling or on-stream analyzing. Composite sampling requires that a representative sample of the flowing stream be taken and stored at operating conditions until the contents can be transported to a laboratory for analysis. On-stream analysis is obtained by using a direct mounted instrument (densitometer) that is capable of measuring the flowing density of the stream that is proportional to flow. The density of the flowing stream is transmitted to a flow computer that accumulates the density and develops a time-weighted average and applies that average to total throughput. The on-stream analysis in the preferred methods since the handling and transportation of samples is not required.

PIPELINE DESIGN CONDITIONS

The following parameters should be considered in the design of an efficient and reliable pipeline metering system;

1. Flow Rate - Design flow rate is based on pipeline sizing and the energy source available to transfer liquid.

2. Working Pressure - Working pressure is a function of the vapor pressure of the product at the highest operating temperature and the total pressure drop between pump stations or storage. Once design working pressure is determined, the LPG transfer pump rate and the piping ANSI rating can be established.

3. Operating Temperature - Product temperature, as well as ambient temperature, must be considered in order to prevent the possibility of measuring vapors instead of liquids.

4. Metering Location – Selecting a metering location is based on the location of the pipeline and the availability of utilities such as power, air, communication links and road access. After a location is selected, line sizes and the available space for metering and proving equipment should be considered. Whether the product lines are to be buried, exposed or insulated should be evaluated.

5. Odorant Requirement – Dependent on applications and market contracts it may be necessary to provide an automatic odorant injection system.

PIPELINE METERING COMPONENTS

Typical components to consider in designing an LPG Pipeline Metering System are illustrated in **Figure 1** and would include the following;

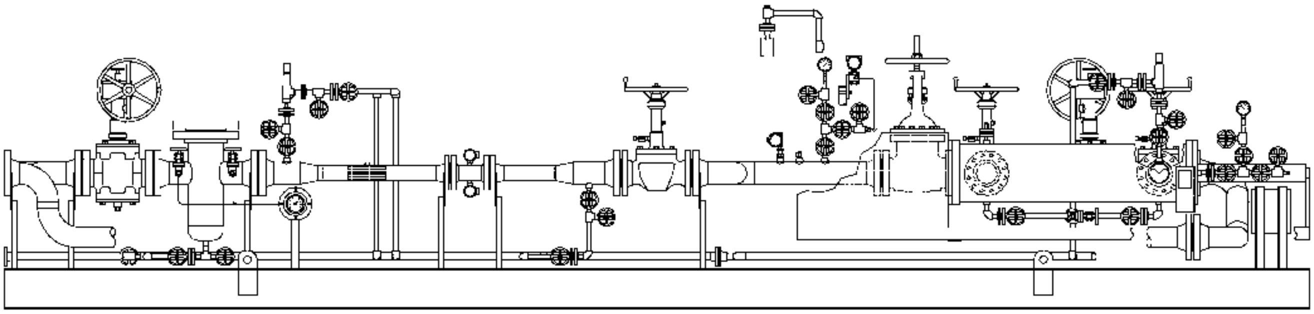

Figure 1

1. Inlet isolating or "ESD" Valve - Emergency shut-down valves (ESD), are self-contained, normally-closed valves which can be actuated on loss of a control signal to automatically shut-down product flow any time there is an emergency condition. These valves should be installed at all critical locations required to protect the pipeline system.

2. Strainer - A strainer is a device which houses a removable perforated basket designed to collect solid materials present in the flowing stream. A strainer is not designed to filter the product, but to collect large contaminants, which may cause damage to the meter.

3. Meter - The meter is the most critical component of an LPG Pipeline Metering System and care should be given in selecting only the most accurate meter. The three most common types of meters in use today are the turbine meter, the positive displacement meter and the coriolis meter.

   * The turbine meter is an inference type meter that derives flow based on properties of the flowing stream, such as angular velocity, which is proportional to flow. Since the turbine meter depends upon properties of the flowing stream, it is necessary to condition flow into the meter using doweled upstream and downstream piping sections in accordance with API Guidelines. Turbine meters use an electronic pick-up coil and preamplifier to transmit meter pulses to an electronic counting totalizer. The turbine meter can be an accurate LPG metering device provided flow parameters are controlled and suitable electronics are used. The advantage of the turbine meter over the positive displacement meter is that it does not use an external packing gland and is less expensive to install and repair. In most cases a turbine meter will be one pipe size smaller than an equivalent positive displacement meter. Disadvantage of turbine meters is the requirement for specialized upstream flow conditioning and these meters develop a higher pressure drop compared to the positive displacement meter.

   * The positive displacement meter determines flow through the use of an internal rotating device by dividing the flowing stream into discrete volumetric segments using a small amount of energy from the flowing stream. Metered volume is transmitted using a mechanical gear train through a packing gland. Any number of meter accessories may be attached to the meter to provide electrical pulse outputs and mechanical totalization. The advantage of the positive displacement meter over a turbine meter is that it is more accurate, does

not require flow conditioning pipe spools and is a low pressure drop device. A disadvantage is the requirement to reduce maximum flow rates through the meter, approximately 25%, due to a lack of internal lubricity of LPG.

* The coriolis meter incorporates bent or curved vibrating tubes that provides a direct measurement of the mass flow rate of a fluid in a closed piping system. Measurement is theoretically unaffected by changes in fluid conditions such as temperature and pressure. Coriolis meters have a very high flow turn-down ratio, which allows the meters to operate over a much wider range than turbine or positive displacement meters. Another advantage is there are no flow restrictions or mechanical components to wear which results in minimal maintenance. Since components do not wear, minimal field calibration is required. Disadvantages include much higher pressure drops than turbine meters and availability in the larger meter sizes. These meters are more expensive than turbine meters but comparable in price to positive displacement meters.

4. Densitometer – A precise inline instrument that uses a slip-stream that continually measures density, proportional to flow. The density of the flowing stream is transmitted to a flow computer that accumulates the density and develops a time-weighted average and applies that average to total throughput

5. Meter Prover Manifold – All types of meters are subject to conditions, which can effect and change the accuracy of these devices such as the changes in fluid characterizes, variations in temperature and pressure, fluid contaminants, and normal wear on internal meter parts. Since the performance of meters is affected by these factors it is necessary to provide a means of proving the accuracy of the meter on a regular basis.

   Major pipeline metering systems should consider the installation of a stationary type prover that is manifolded into the main piping system, which would allow meter proving on a regular basis. The most common provers used for LPG meter calibration are the bi-directional prover and the small volume prover.

   Regardless of the meter selected for custody transfer, provisions must be made to allow for meter calibration. A simple solution is to provide a three-valve prover manifold using two piping tees with two valves side-mounted between an inline valve. The inline valve must be a quality block and bleed type with provisions to determine seal leakage during a meter calibration, since every drop of liquid going through the sales meter must go thorough the prover system. The prover manifold allows the sales meter to be placed in series with a proving device of a traceable and known volume. The prover manifold should be furnished with a temperature indicator, an accurate temperature transmitter, a pressure gauge and an accurate pressure transmitter. The temperature and pressure transmitters are used to communicate to the electronic flow computer and to the proving system during a meter proving.

6. Control Valve - Installation of a control valve that is capable of providing back pressure and flow control is the key to accurate metering. Back pressure control is accomplished by continually monitoring temperature and pressure during metering to insure that product is always metered above vapor pressure, regardless of the product flowing temperature. Typical valve control is from a self-contained back pressure controller mounted directly to the valve or from an electronic signal from a flow computer. It is important to consider a dynamically stable, pneumatically operated diaphragm valve rather than a self contained valve dependent upon LPG energy and differential pressure across the valve to provide control.

Maintenance problems are greatly reduced by using the diaphragm type valve, with the only disadvantage being that instrument air or nitrogen is required for operation.

7. Safety Features - Safety features should include automatic emergency shut down (ESD) valves, which are designed to shut down the pipeline when activated locally or from a remote location. Additional safety devices that should be considered include fire sensors and combustible gas detectors.

8. Flow Computer – The application may dictate the installation of a local or remote Flow Computer designed to interface with and control the pipeline metering system. Typical Flow Computers offer features such as automatic calculation of metered volumes, back pressure and flow rate valve control, automatic proving, meter factor trending, archiving of data, batch run ticket printing and the ability to export databases to a remote host computer system.

9. Communication or SCADA Building – Provide a climate controlled building to house the flow computer and any other communication systems that may be required.

10. Meter Prover System – The most common prover system used for LPG meter calibration is the bi-directional meter prover. The basic principal of operation of the Bi-Directional meter prover is to provide an accurate and repetitive displacement of liquid through a pre-calibrated volume between two detector switches. Accurate displacement of the liquid is accomplished by forcing an inflated spheroid through a calibrated section of pipe using fluid energy from the stream being metered and recording the metered volume. Since the entire stream of fluid being metered flows through both the meter and the prover, a ratio known as "meter factor" can be determined between the known volume and the volume registered by the meter. This meter factor is used as a multiplier and applied to the volume shown on the meter register to determine true quantity of fluid passing through the meter.

The advantages of the Bi-Directional meter prover system are that proving is done under actual operating conditions and the meter runs continuously. This procedure eliminates errors resulting from starting and stopping and also reduces proving time. Another advantage is that proving temperatures are stabilized during continuous proving.

A typical system, including major components is illustrated in **Figure 2**

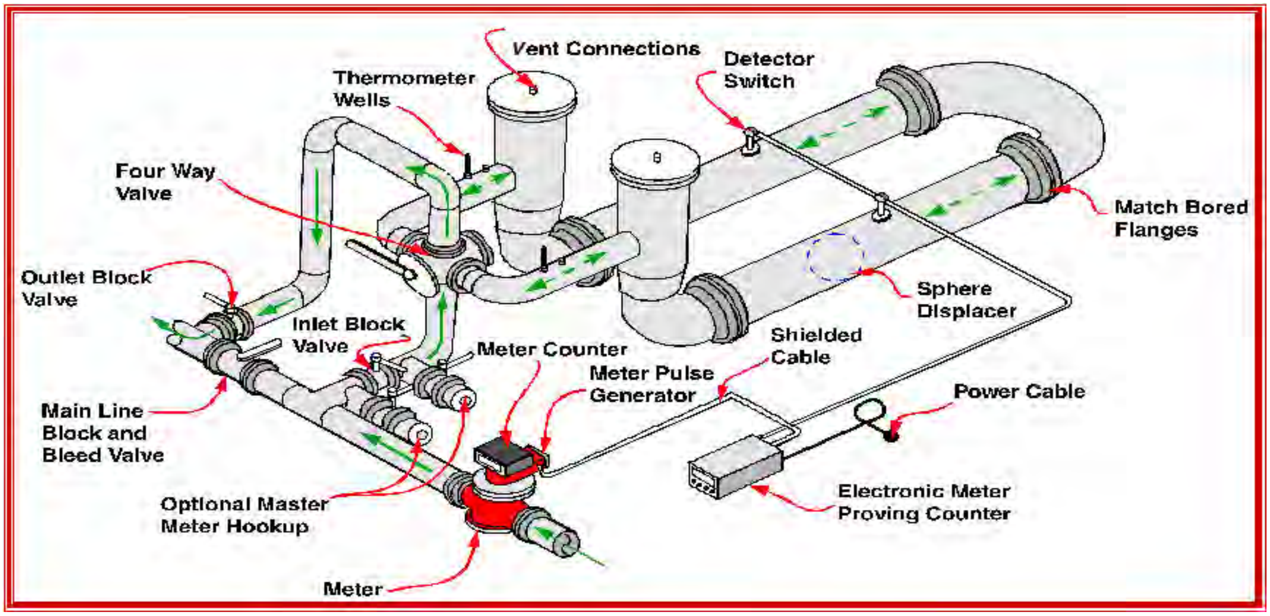

Figure 2

- Four-Way Diverter Valve - used to divert flow through the prover system without interrupting flow. Since there is not a closed position on the valve, flow can only be diverted.

- Launch Chambers - used to retrieve the spheroid after each run. Launch chambers are also used to help reduce the velocity of the spheroid after completion of a run.

- Calibrated Measuring Section - referred to as the volume between detector switches and is expressed as a "round trip".

- Pre-Run - a section of pipe located upstream of the detector switches to allow ample spheroid travel time (based on fluid flow rate) before contact with the first detector switch. Pre-run is required to ensure that the four-way valve is fully seated before the spheroid contacts the first detector switch.

- Detector Switches - used to electrically detect the passage of the spheroid and to trigger a gating circuit in the electronic meter prover counter.

- Spheroid - an inflatable device that is used to displace fluid through the calibrated measuring section.

- Meter Pulse Generator - an electronic device that is attached to the gear train of the meter to be calibrated that is designed to transmit high resolution electrical pulses to the electronic meter prover counter.

- Electronic Meter Prover Counter - used to receive high resolution electrical pulses from the meter to be calibrated. The prover counter is started and stopped by the actuation of the prover detector switches based on the passage of the spheroid.

- Water Draw - a procedure used to calibrate a Bi-Directional meter prover by collecting water displaced by the spheroid into containers of known volume that have been certified by the National Institute of Standards And Technology (NIST).

ODORANT INJECTION SYSTEM

Some LPG pipeline applications may require that product be odorized. Since LPG is colorless, odorless and heavier than air in the vapor state, it is necessary to add an artificial odor to warn users of its presence. The most common odorant in use today is ethyl mercaptan. Most authorities require a minimum of 1.0 pound of odorant be injected into 10,000 gallons of LPG. Due to a condition called "odorant fade", which occurs in new tanks and piping systems, and to allow a margin of safety, most installations agree on an odorant rate of 1.5 pounds of odorant per 10,000 gallons of LPG loaded.

The basic design of an Automatic Odorant Injection System should be to provide a simple, reliable, “leak free” and fail-safe means of injecting odorant into an LPG stream proportional to metered flow. A basic requirement is to provide a “hard copy” of the amount of odorant injected in order to protect LPG Operating Facilities with an “audit trail”.

A fail-safe automatic odorant injection system should be selected that injects odorant proportional to flow and provides a printed record of the odorant injected for each batch transaction. The system must be designed to alarm any time an odorant malfunction develops.

A typical odorant system design using a pressurized nitrogen storage tank and an odorant injector is illustrated in **Figure 3**

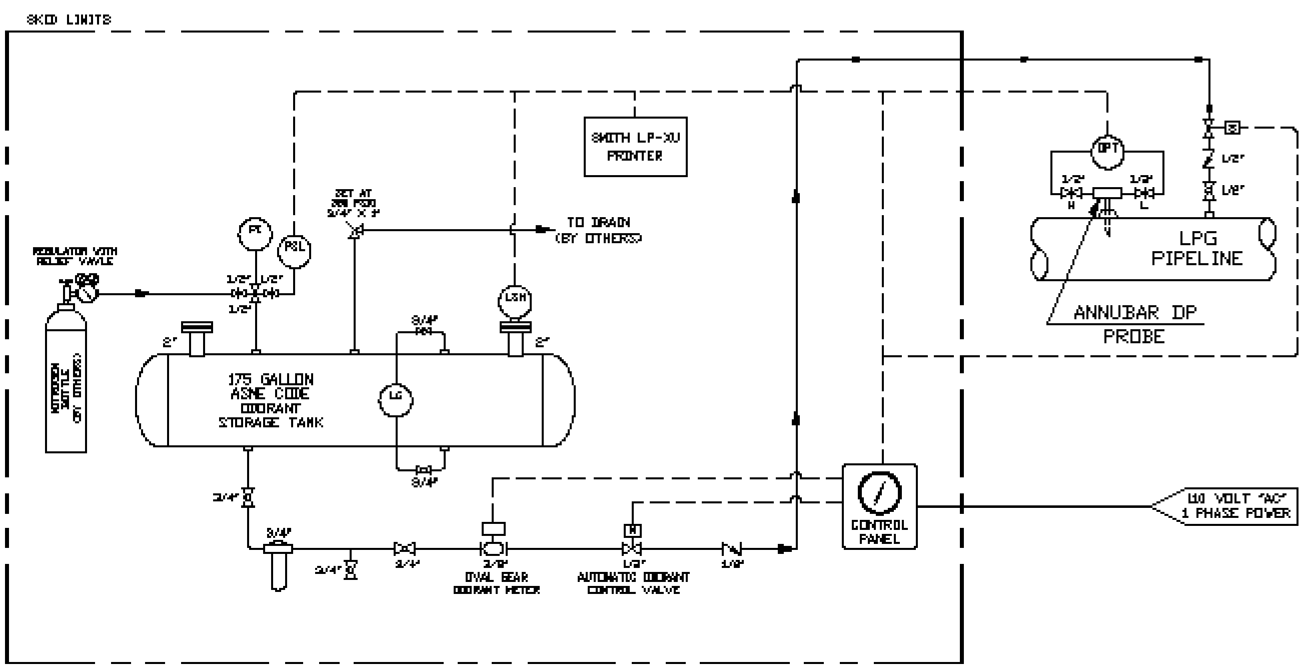

Figure 3

SUMMARY

Through good engineering design and planning, a safe and reliable system can be provided to achieve accuracy, reliability, dependability, ease of operation, safety, and conformance to prescribed standards. This attention to detail will yield a trouble free and accurate LPG Pipeline Metering System requiring a minimum of supervision and maintenance.