DESIGN, OPERATION & MAINTENANCE OF L.A.C.T. UNITS

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INTRODUCTION

The two most common methods of measuring the volume of petroleum liquids are tank gauging and liquid metering. The problems associated with tank gauging are (1) it requires that an operator make an accurate liquid level determination by climbing to the top of the tank to be gauged, (2) that an operator make an accurate average liquid temperature determination, (3) that an operator make an accurate sediment and water content analysis and (4) that the tank be static, which means that no liquid can enter or leave the tank during gauging. Once the contents of the tank are removed, it is necessary to regauge the tank.

Since crude oil is sold on the basis of temperature, API Gravity and the amount of Basic Sediment and Waste (BS&W), it is very important to make accurate measurements. The greatest effect on volume is temperature — typical crude oil will expand and contract at the rate of 2% per 40º F temperature change. The accumulation of errors present in the tank gauging may be as high as 1%. The potential annual losses in revenue, based on daily lease production and on $90.00 per barrel oil, would be as follows in table 1.

The simplest and most effective way to transfer the ownership of liquid hydrocarbons between a buyer and a seller is through the use of an accurate liquid meter. With the aid of additional components, the liquid meter is capable of unattended measurement with maintained accuracy's of 0.25%, or better. This measurement system is commonly referred to as a Lease Automatic Custody Transfer (LACT) Unit when ownership is transferred at a production lease. When ownership is transferred away from a production lease, such as a transfer between Pipeline Companies, a measurement system may be referred to as an Automatic Custody Transfer (ACT) Unit.

TYPICAL LACT UNIT

A typical LACT Unit would include the following major components:

Typical L.A.C.T. Schematic

The simplest approach to the understanding of the overall operation of a LACT unit is to review the operation of the individual components that comprise a typical unit, which would include the following:

CHARGE PUMP AND MOTOR

The charge pump and motor are the primary energy source for the entire system and the careful selection of this unit is very important. Occasionally design parameters change and it may be necessary to make modifications or changes to the charge pump or the motor after the unit has already been placed in service, therefore it is important that operators understand the design aspects of the charge pump, to ensure the satisfactory operation of the entire system. In order to correctly size a charge pump system, it is necessary obtain the following design information;

1. Design flow rate - this is the normal flow required by the system during pumping operation. This flow may be expressed in gallons per minute (GPM), in barrels per hour (BPH) or in barrels per day (BPD). Most pump curves display flow rate in GPM so it may be necessary to convert flow units.

2. Gravity - this is the relative weight of the product which may be expressed as Specific Gravity (S.G.) or API Gravity. A gravity determination is required to develop the discharge pressure requirements of the pumping system. A correlation between S.G. and API Gravity is as follows;

$$\text{S.G. (Specific Gravity)} = \frac{141.5}{131.5 + \text{API Gravity}}$$

$$\text{API Gravity} = \frac{141.5}{\text{S.G.}} - 131.5$$

3. Discharge pressure - this is the discharge pressure required by the system at the design flow rate. This discharge pressure may be expressed in pounds per square inch (PSI) or in total head, which is related to feet of water required to produce the discharge pressure. A formula for converting from PSI to Total Head is as follows;

$$\text{Total Head} = \frac{\text{PSI x 2.31}}{\text{S.G.}} \quad \text{Or} \quad \text{PSI} = \frac{\text{Total Head x S.G.}}{2.31}$$

4. Net Positive Suction Head (NPSH) - this is the energy available to supply liquid to the suction of the pump due to the position and location of the liquid and is usually expressed in terms of feet. "NPSH Available" relates to the energy available to the pump while "NPSH Required" relates to the minimum energy required by the pump. It is very important that the NPSH available is always greater than the NPSH required by the pump at all flow rates, since NPSH required increases as pump flow rate increases. If NPSH available is not greater than NPSH required, the pump will not be able to produce the flow rate and discharge pressure required and damage to the pump could occur if allowed to operate for any length of time.

Once the above design information has been determined, it will be necessary to select a suitable pumping system. The choice will usually be either a centrifugal pump or a positive displacement pump depending on pressure, flow rate and NPSH available. Normally a high flow rate with low discharge pressure and a high NPSH available will dictate a centrifugal pump while a high discharge pressure, low flow rate and low available NPSH will require a positive displacement type pump. We will limit our discussion to the centrifugal pump which is a shaft driven rotating wheel with vanes that generates energy when it is rotated. The principal is the same as rotating a bucket, filled with water, with a hole in the bottom - as the bucket is rotated faster and faster, the amount of water discharged is greater and the force of the water discharged is greater. In the case of the centrifugal pump, the rotating wheel is called an impeller and the diameter of the impeller governs the discharge pressure. The flow rate and discharge pressure are also controlled by the constant speed of the motor which directly drives the pump at a speed of either 1750 RPM or 3600 RPM.

Pump selection is usually made from "Pump Curves" that are supplied by the manufacturers. These pump curves are generally provided for different motor driven speeds and show a family of curves - one curve for each impeller diameter. Also shown are "Efficiency Curves", which show the manufactures pump efficiencies at different operating conditions of head and flow. NPSH requirements are normally shown for different impeller sizes at different flow rates. Brake Horsepower (BHP) lines are shown on the pump curves, but these are for water with a S.G.=1.0 and should be corrected for actual operating gravity. The typical formula for brake horsepower at any condition of head, flow and efficiency is as follows;

$$\text{Brake Horsepower} = \frac{\text{Flow Rate (GPM) x Discharge Pressure (PSI)}}{\text{1715 x Pump Efficiency}}$$

For the purpose of operation of the L.A.C.T. Unit, it is assumed that all piping has been satisfactorily connected to the inlet connection of the pump from the "Run" or "Surge" tank and that no undue strain has been placed on the pump case by the field piping. Prior to operating the LACT Unit, it is recommended that the following precautions be taken to protect the operation of the charge pump and motor;

1. Verify the operating voltage to the electric motor - incorrect voltage could permanently damage the electric motor

2. Verify the rotation of the pump - incorrect rotation can greatly effect the hydraulic output of the pump and may even damage the pump by reversing the impeller from the pump shaft.

3. Verify the alignment of the coupling connecting the electric motor to the pump.

STRAINER

In some cases an inline strainer may be installed immediately upstream of a charge pump or a positive displacement meter to remove liquid entrained derbies to help prevent damage to the pump or meter.

The strainer is a device which houses a removable perforated basket which is designed to collect solid materials which are present in the flowing stream. The strainer basket will trap and collect all materials that are larger than the perforations in the basket. Inline strainers are normally designed to collect a sizeable amount of derbies, but if the strainer basket is not cleaned on a periodic basis, the strainer basket is capable of rupturing, due to a high differential pressure build-up and then all the collected derbies will be emptied into the pump or meter causing very serious damage.

It is recommended that the strainer basket be removed and cleaned on a frequent basis during LACT Unit start-up, or until the piping system has had a chance to clean up. In some cases, it may be desirable to install a differential pressure gauge across the strainer to visually display the pressure loss across the strainer basket during flowing conditions. In severe cases, it may be advisable to install a differential pressure switch across the strainer to electrically alarm the operator to a high strainer basket differential pressure.

AIR ELIMINATOR

An air eliminator is a device that is used to remove entrained air or vapor from the fluid stream before it enters the meter. Should air be allowed to enter the meter it would be measured as part of the flowing stream, resulting in meter inaccuracy. The air eliminator is installed upstream of the meter in the highest part of the piping system to allow air to migrate and accumulate until it is eliminated.

Air eliminators operate using a float that is mechanically attached to an exhaust valve. The float is designed to float in the fluid and not in the air. As air or vapor accumulates in the top of the air eliminator, the liquid level is forced down until the float drops and the air is discharged through the exhaust valve to an atmosphere sump or drain. To prevent the air eliminator from inhaling or sucking in air when the float is down and the LACT unit is not in operation, it is important to install a "soft seated" check valve on the discharge of the air eliminator.

BS&W PROBE AND MONITOR

An electronic device that is capable of determining the amount of Basic Sediment and Water (BS&W) is an internal part of most LACT Units. The system consists of an inline "BS&W Probe" that monitors the entire flowing stream and communicates to an electronic device, called a "BS&W Monitor" that produces an electrical control signal based on the amount of BS&W present in the flowing stream. The ability of this system to accurately signal the LACT Unit on excess BS&W content insures that only the highest quality of "Merchantable Oil" is delivered to pipeline and the pipeline is not having to transfer undesirable BS&W. The electrical control signal feature of the BS&W Monitor is used to control a diverting valve which diverts the fluid stream back to a retreating facility whenever the BS&W content exceeds the Monitor setting. If the BS&W content of the flowing stream drops below the Monitor setting, the diverting valve returns the fluid to the pipeline and normal automatic operation continues.

The BS&W Probe is an internally plastic coasted piping section that is generally installed in a vertical run of pipe. The probe is equipped with an internal sensing device that measures the dielectric constant (internal capacitance) of the flowing stream. As the amount of BS&W changes for a particular gravity of crude oil, so does the dielectric constant. With the aid of the BS&W Monitor, a BS&W adjustment can be set that will provide an electric output when the percentage BS&W setting is exceeded. BS&W Monitors are generally furnished with the following features;

1. Adjustable BS&W Range - 0 to 3% in increments of 0.1%.

2. A BS&W Indicator is provided on some units to display the amount of BS&W in the flowing stream during operation, while other units use a "null meter" that is required for field calibration.

3. "Fail Safe" feature which will alarm the LACT for a shutdown should the BS&W Monitor electrical system

fail.

4. Time delay - an adjustable device that is used to delay an excess BS&W signal to prevent inadvertent alarms due to small slugs or pockets of BS&W.

Some means should be provided in the piping to allow field calibration of the BS&W Probe. Some systems require that the probe be calibrated by filling the unit with a "dry" or water free sample of the fluid being handled. Other systems require an input based on a sampling of the flowing BS&W content.

DIVERTER VALVE

The diverter valve is a three-way two-position valve that is installed upstream of the meter and used to divert flow whenever the BS&W content of the fluid stream exceeds the setting of the BS&W Monitor. The diverter valve has three different piping ports that are connected to the inlet piping from the pump, the divert piping to the retreating facilities and the downstream piping to the meter. The diverter valve is equipped with either an electric, hydraulic or pneumatic actuator which is connected to an internal shaft and plug which controls the flow path of the valve. When the LACT Unit is shutdown or an excess amount of BS&W is detected, the actuator positions the valve to a normal divert or "fail closed" position. When the unit is running and the BS&W content is below the BS&W Monitor setting, the actuator positions the valve to a "run" position to allow total fluid flow through the meter.

SAMPLER SYSTEM

The sampler system consists of a probe that is used to retrieve a representative sample of the flowing stream and a sampler container that is used to store the collected samples over a specified time period. The contents of the sample container is used to determine the true representative valve of the entire metered stream during the custody transfer. The representative sample contents will determine composite API Gravity and the total percentage of BS&W. It is therefore, very important to ensure accurate and representative samples.

The sampler probe is a section of pipe that is installed in a horizontal position in a vertical run of pipe upstream of the meter. The tip of the probe is beveled to a 45 degree angle and is inserted with the bevel located in the center of the pipe with the bevel facing the direction of flow.
The outlet of the sampler probe is connected to a three-way electric operated solenoid valve. The solenoid valve is also connected to the sample container and to a "volume regulator". The volume regulator is an adjustable device with a spring return mechanism that is designed to collect a precise amount of fluid each time the solenoid valve is actuated. With no power on the three-way solenoid valve, the sample probe is isolated or blocked and the volume regulator and the sample container are internally connected. When the LACT Unit is in operation and the sampler solenoid is electrically actuated or "energized", the sample probe is connected to the volume regulator and fluid under line pressure is allowed to fill the volume regulator and compress the spring load assembly. As soon as the sampler solenoid is de-energized, the trapped fluid, under pressure, in the volume regulator is injected into the sample container using both the fluid trapped pressure and the spring load assistance of the volume regulator.
The sampler solenoid is actuated by a transmitter or pulser located on the meter to allow sampling at a fixed rate (one sample per barrel, etc.) only during metering. The sampler does not operate when the meter is not in operation, i.e., periods of shutdown or during an excessive BS&W divert sequence. Other types of sampling probes may use either an electric or a pneumatic actuator to retrieve or extract the sample from the flowing stream.

The sample container is a storage vessel that is used to collect the contents of all the samples taken during the custody transfer. The container is sized to allow adequate storage during the total custody transfer period, usually 30 days. It is important that the container be vapor tight to prevent the evaporation and loss of entrained vapors. Sample container should be furnished with the following;

1. Quick closures - used to allow inspection and cleaning after each custody transfer.

2. Internal coating - used to prevent corrosion and to allow adequate rundown and drainage.

3. Sight glass - used to visually determine the amount of collected sample.

4. Circulating pump - used to agitate and circulate the contents of the sample container.

5. Spray bar - used to wash the sides of the container and to ensure a homogeneous mixture through agitation and circulation.

6. Pressure gauge - used to determine the internal pressure of the sample container.

7. Relief valve - used to protect the sample container for over pressure.

8. Miscellaneous valves to allow sample draw off and to allow discharge of the contents of the sample container.

METER

The meter is used to accurately and precisely measure the total fluid stream and to accumulate the total throughput. The most accurate meter used is the positive displacement meter. The positive displacement meter uses the energy of the flowing stream and divides the stream into small segments through rotation of an inner unit. This precise rotation is connected through a mechanical gear train to a mechanical counter to develop the total throughput of the LACT Unit. In order to provide the many functions required, the following meter accessories may be used;

1. Temperature Averager – use to collect weighted average temperature so delivery ticket can be adjusted to 60 F to "Net" total delivery.

2. Low Resolution Transmitter - used to electrically actuate the sampling system.

3. Right Angle Drive - used to mechanically connect the gear train of the meter to a portable high-resolution photo- electric transmitter used for meter proving and calibration.

4. Counter - a non-resettable type mechanical counter used to accumulate the total throughput of the LACT Unit.

5. Meter Monitor Pulser - an electrical transmitter that is mechanically attached to the counter to be used to alarm the LACT Control Panel anytime the meter is not turning and the LACT Unit has been signaled to operate.

Other meter accessories may be employed on a LACT Unit depending on the application. In some cases electronic Temperature Averagers may be used in lieu of mechanical temperature compensators.

METER PROVER LOOP

The meter prover loop is a manifold using three valves connected to two tees. The typical arrangement is to install the valves and tees so that two of the valves are side mounted and one valve is in line. This arrangement allows another meter or "prover system" to be connected to the side mounted valves. By closing the inline valve, all fluid going through the meter would also go through the prover system. The inline valve becomes the "inline prover valve" and since every drop that goes through the meter must go through the prover system, it is necessary that this valve have special internal seats and seals so that any seal leakage can be detected. The most common seats used by the inline prover valve are "block and bleed" seats. The inline prover valve is also furnished with a "tattle-tale" drain valve that can be opened, when the valve is in the closed position, to verify that no leakage occurs across the valve during a proving run.

The tees that make up the meter prover loop are furnished with thermowells and pressure gauges that are used to compare flowing temperatures and pressures with the prover system during meter calibration.

BACK PRESSURE VALVE

The back pressure valve is an automatic valve that is used to hold a minimum pressure against the entire LACT Unit. This valve is required to ensure that the meter always operates against a pressure above the vapor pressure of the fluid being metered. When a centrifugal charge pump is used, the back pressure valve holds a constant pressure against the pump which maintains a constant flow rate on the meter. Provided the back pressure setting is always above the vapor pressure of the fluid, it is possible to adjust flow rate through the meter by adjusting the valve.

Back pressure valves are a two-way type valve equipped with an adjustable spring loaded diaphragm actuator connected to an internal shaft and plug. A pressure sensing line is installed from an upstream connection on the valve body to the diaphragm actuator so that upstream line pressure is always in communication with the diaphragm, which works directly against the spring setting of the valve. With the pump not running the valve is in a normally closed position. As the pump delivers product above the spring setting of the actuator, the valve opens. The valve is open above the spring setting and closed when the pressure is below spring setting.

In most cases, it is recommended that a back pressure valve also be installed on the discharge side of the diverter valve to prevent the charge pump from operating a very high flow rate due to a lack of back pressure.

CHECK VALVE

A check valve is used to prevent backflow of metered fluid from the pipeline back through the LACT Unit. The check valve is installed as the last device in the piping system. The check valve is a two-way type valve with a hinged flapper that allows fluid to pass through the valve in one direction only. Should fluid attempt to reverse direction, the flapper in the check valve contacts a seat to prevent flow.

LACT CONTROL PANEL

The LACT Control Panel is the electrical brains of the LACT Unit and controls the entire operation of the system. The basic system operates on liquid level switches installed on the "run tank" or "surge tank". When a high level is signaled in the run tank the LACT Control Panel will start the charge pump. Provided there are no problems during operation, the system will run until a low liquid level is signaled and the unit will shut down until the next high level signal is received. In addition to starting and stopping the LACT unit from level switches, the following features are also provided;

1. Main Power On-Off - a circuit breaker or fused disconnect switch to be used to remove power from all electrical devices on the LACT Unit.

2. Hand-Off-Automatic Switch - used to run the LACT charge pump in a manual or automatic mode.

3. Lightning Arrestor - used to help absorb the electrical surges from lightning.

4. Divert Controls - used to position the diverter valve based on signals received from the BS&W Monitor.

5. Monitor Failure control - used to shutdown the system in the event of a failure of the BS&W Monitor.

6. Meter Malfunction Control - used to shutdown the system in the event the meter does not register when the LACT Unit is in operation.

7. Set Stop Allowable Control - sometimes used to shutdown the LACT Unit if a preset quantity of product has been delivered through the system.

8. Alarm Beacon - used to alarm an operator anytime there is a failure on the LACT Unit.

SEALING

Any device that affects the quality or quantity of the measurement of the LACT Unit must have a means of security sealing. Such items would include the BS&W Monitor, the Sampler Probe and Sample Container valves and components, Meter and Meter Accessories, Prover Valves, Back Pressure Valves and the LACT Control Panel.

Table 1

DAILY LEASE PRODUCTION	LOST REVENUE FROM GAUGING PER YEAR @ 1%	LACT UNIT MEASUREMENT ACCURACY 0.25%	ADJUSTED LOST REVENUE PER YEAR
500 Barrels	$ 164,250.00	$ 41,063.00	$ 123,187.00
1000 Barrels	$ 328,500.00	$ 82,125.00	$ 246,375.00
1500 Barrels	$492,750.00	$ 123,188.00	$ 369,562.00
2000 Barrels	$657,000.00	$ 164,250.00	$ 492,750.00