Chapter 3

The Operation of LPG Liquid-Measuring Systems

Objectives

Upon completion of this chapter, you should be able to:

1. Identify specific elements of an LPG liquid-measuring system and describe their function and operation.

2. Describe major differences in design and operating characteristics of these elements that are encountered in the field.

3. Describe the principle of positive-displacement liquid measurement.

Introduction

In this chapter we will take a closer look at each of the major operating elements of an LPG liquid-measuring system. A variety of designs are in common use, and new features are being incorporated in metering equipment almost continuously with advances in technology and changes in the marketplace.

In the interest of providing an introduction that is both thorough and comprehensible to the official who has not had extensive experience with these devices, we will not attempt to cover specific features of every model available from each of the manufacturers. You will acquire this specific knowledge most effectively through experience in the field. This chapter will instead focus on design features and operating characteristics that are common to the range of metering equipment you are most likely to encounter. In some cases, illustrations of particular designs are used. These are intended to help you to understand typical features, not to familiarize you with specific makes and models.

For purposes of organizing the discussion, we will look separately at groups of components that are involved in similar functions: the intake line, the measuring and indicating elements, and discharge and control elements. In this scheme of things the measuring elements are at the center of the system, as in a very real sense they are. However, it is a misconception to think that accuracy of measurement depends exclusively upon the measuring and indicating elements. An LPG liquid-measuring system is designed to measure and deliver product simultaneously, and the efficiency of one function depends very much upon the efficiency of the other. It should become clear as we proceed that we are dealing with a system in which various components that perform different functions are dependent upon one another.

The Intake Line

The intake line consists of the entire liquid flow path from the storage tank to the inlet of the meter, along with a number of elements that control the flow of liquid and assure that it maintains its liquid state. These components are illustrated in Figure 3-1.

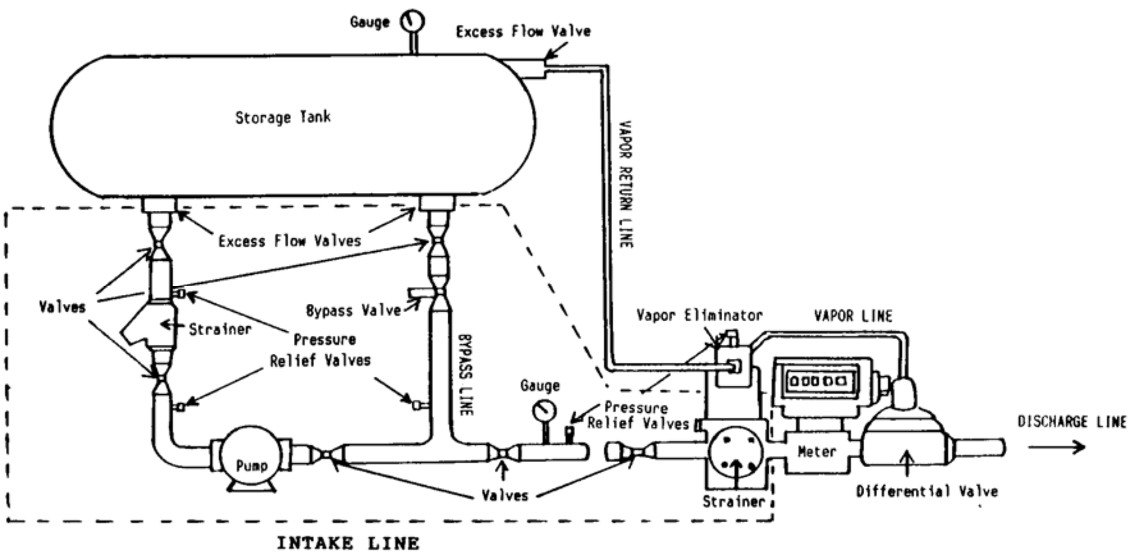


Figure 3-1. The intake line.

Pumps

As you learned in Chapter 2, the receiving vessel to which product is delivered is, like the metering system, closed. When the two are connected they form a larger closed system. Because the receiving tank is full of vapor and some liquid, gravity cannot be used to propel product to its delivery point. As a result the metering system must use a pump to draw product from the storage tank and propel it through the meter and discharge line to the receiving tank.

Several different designs of pumps are in common use, including turbine pumps, gear pumps, and sliding-vane pumps. The type and design of the pump selected will depend upon such factors as the desired flow rate and working pressure. Examples of all three types are shown in Figure 3-2. As the pump turns, product is displaced through the outlet, momentarily creating a lower pressure at the inlet. The pressure of vapor in the storage tank on the surface of the liquid product pushes liquid into the intake line and toward the pump to relieve this condition. The rate at which the pump displaces product through its outlet is a function of the speed at which the pump turns, its design, and the size of the piping at its outlet.

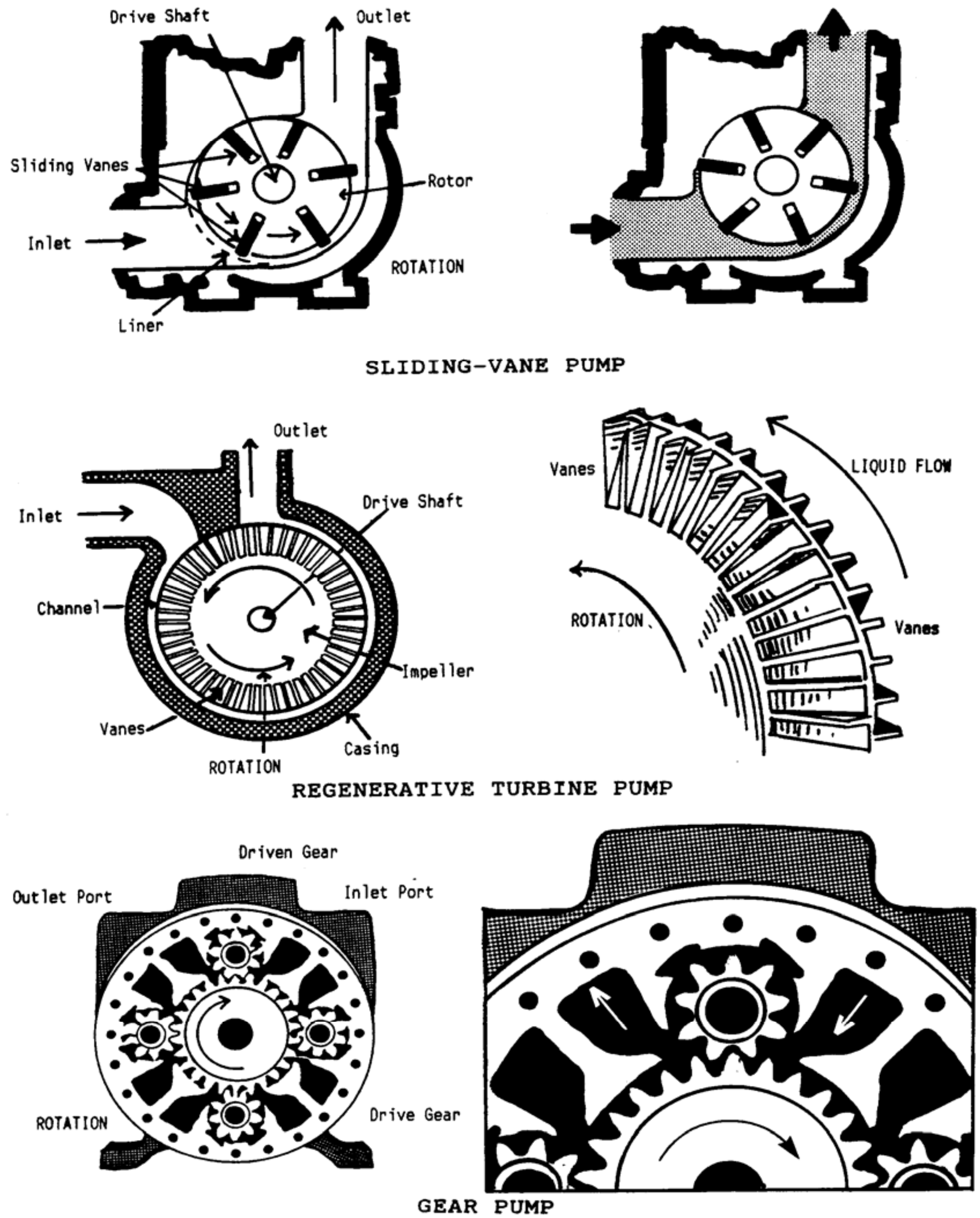


Figure 3-2. Typical pump designs.

Pump speed can become a critical factor in the measurement accuracy of the system. If the pump speed is too high, the pressure at its inlet can fall below the vapor pressure of the product, and some vaporization will occur (this is usually called "flashing"). Vapor bubbles introduced into the liquid flow in this way can pass through the meter and result in some degree of over-registration. The technical name for this process is cavitation.

To minimize the vapor-producing effects of cavitation, the length of piping leading from the storage tank to the pump should be kept to a minimum to reduce pressure loss due to friction. This piping should also be one size larger than the piping leading from the pump outlet (to reduce the pressure differential), and restrictive fittings should be avoided in close proximity to the pump inlet. The pump selected should also be of the proper size and should operate at the correct speed for the system.

Bypass

For brief periods of time, especially at the end of a delivery, the pump is in operation while no product is being dispensed, or is being dispensed at a low flow rate. To prevent damage to the pump during these intervals, most pumps are equipped with an internal bypass circuit, as illustrated in Figure 3-3.

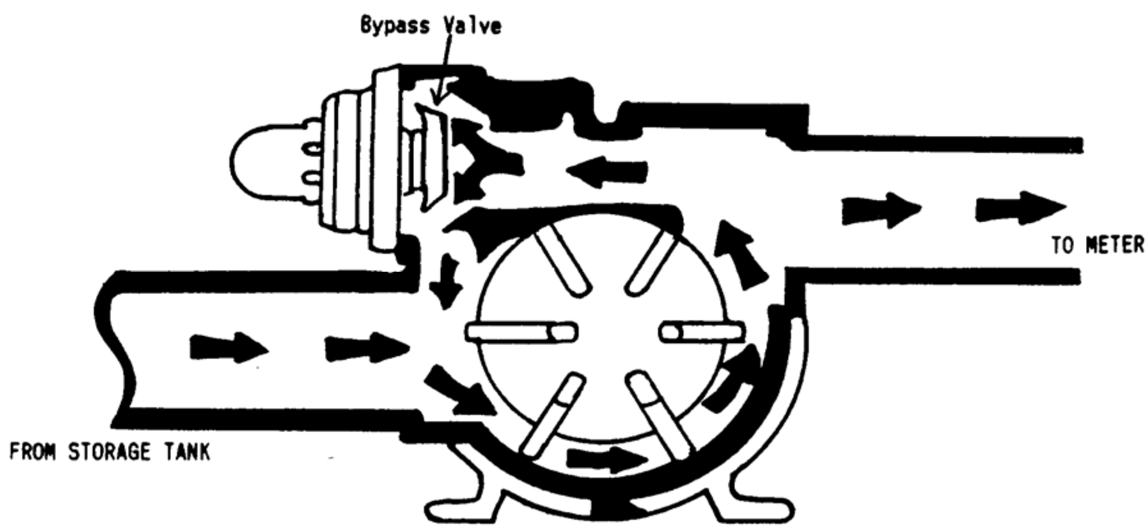


Figure 3-3. Pump internal bypass circuit.

When flow is restricted, pressure inside the pump rises. When it reaches a predetermined pressure, the spring-loaded bypass valve is forced off its seat, allowing liquid to circulate inside the pump. When flow resumes through the system, pressure on the bypass valve will drop and the spring will seat the valve, closing off the circuit. The problem with this design, necessary as it is to protect the pump, is that circulating product will be heated by friction and this heat is likely to promote vaporization. As long as the product continues to circulate within the pump, vapor bubbles will tend to accumulate in the bypass circuit; when the bypass circuit is closed, the entrained vapor is introduced into the flow headed toward the meter. To overcome this source of vapor production, most manufacturers recommend that an external bypass circuit be installed. A typical configuration is shown in Figure 3-4.

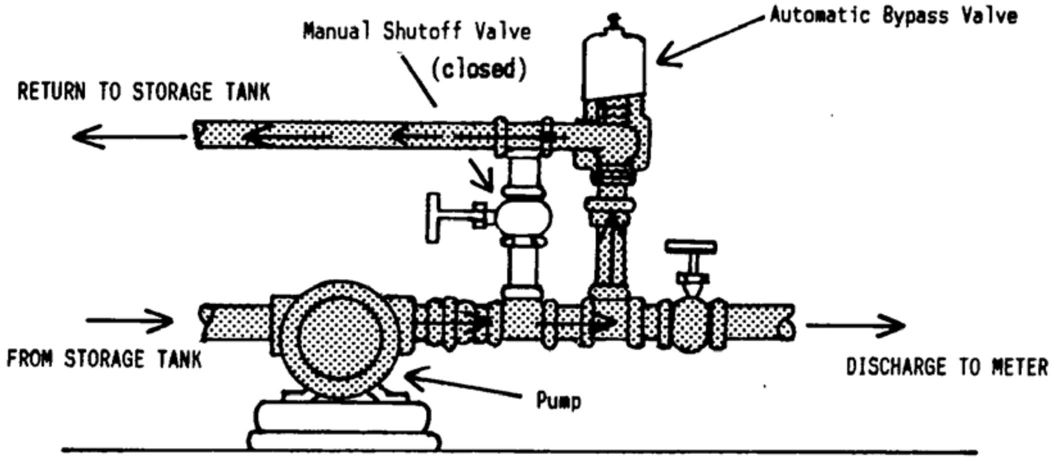


Figure 3-4. External pump bypass circuit.

This design permits product to be recirculated through the storage tank (as you may be able to see more clearly in Figure 3-1), allowing vapor produced during passage through the pump to rise into the tank vapor space and continuously supplying the pump with unheated liquid product. To allow the external bypass circuit to replace the function of the internal circuit, the bypass valve in the former is calibrated to open at a pressure that is lower than the internal valve by about 15 to 20 psi. Notice that the bypass circuit shown in Figure 3-4 also includes a manually controlled bypass across the automatic bypass valve. This permits the bypass circuit to be held open continuously, as may be necessary for various reasons such as purging or cleaning of the lines.

Excess Flow Valves

As can be seen in Figure 3-1, all outlets from the storage tank, including the vapor port, are equipped with excess-flow valves. The purpose of these valves is to shut off flow from the storage tank in the event of a hose or line rupture in the delivery system. They are designed to allow product to flow under normal operating conditions; if the flow rate exceeds this range, the excess-flow valve(s) close automatically. When the system downstream of the valve is once again pressure-tight, the excess-flow valve re-opens automatically.

If, for example, the discharge hose were to rupture, product under system pressure (100 psi or greater for propane if the liquid is at or above 60 °F) would be forced through the opening into the atmosphere, causing an extremely dangerous situation. If the system was not equipped with excess-flow valves, many gallons of highly flammable LPG would be emitted before the operator could take effective action to shut off the system manually. (If ignition of the leaking vapor were to occur, it might be impossible for the operator to take any effective action to control the emission.) However, the excess-flow valves would halt the supply of product from the storage tank almost instantly in response to the rapid flow of liquid, limiting the amount of leakage.

Pressure Gauges

Pressure gauges should be installed in the intake line as it approaches the meter and also in the storage tank vapor space. Monitoring pressure in the intake line provides the operator with information needed to determine whether the system is operating correctly and also warns of pressure buildup that might harm the pump, meter, or other components of the system. Comparing readings from the two pressure gauges will also indicate whether the system is operating correctly. As you will learn in later chapters, these pressure gauges are also used when performing volumetric tests on the delivery system.

Relief Valves

The intake line is also equipped with hydrostatic pressure relief valves. A typical pressure relief valve is illustrated in Figure 3-5. Pressure relief valves perform a crucial safety function. They protect piping between two shut-off valves from excessive pressure and possible rupture. As can be seen in Figure 3-1, pressure relief valves are installed in any portion of the system that can be isolated in this way.

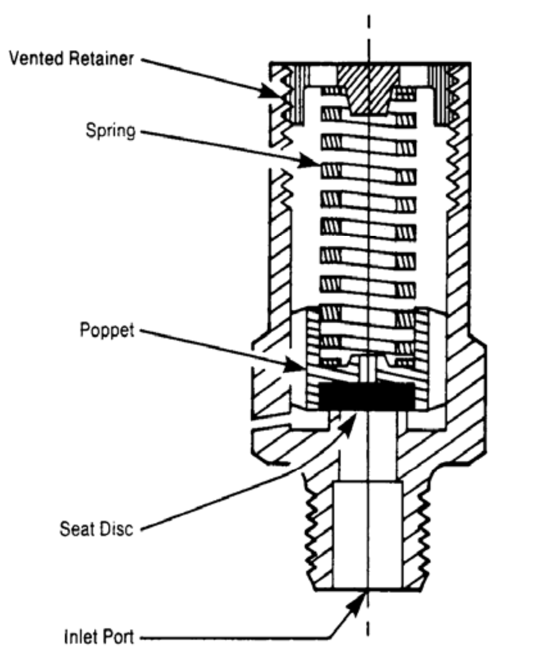


Figure 3-5. Hydrostatic pressure relief value (closed).

Under normal operating conditions these valves remain closed since pressure in the piping is well below the set start-to-discharge pressure of the valve (that is, the pressure that would cause the valve to open). Generally, a critical pressure condition will arise when piping or hoses that are full of liquid product are closed off at both ends and the liquid has no room to expand when its temperature rises from sun exposure or when the system as a whole is exposed to high heat, as in a fire. For a detailed discussion of the operation of relief valves in emergency situations, see Chapter 4.

Vapor Eliminator

At the meter end of the intake line is the vapor eliminator (see, again, Figure 3-1). Its purpose is to remove vapor before it can enter the meter and cause over-registration. Vapor separated from the liquid flow is vented from the top of the vapor eliminator into a line that carries it back to the storage tank vapor space. As we have seen, vapor can be introduced into the fluid flow by pump cavitation or heating of product in the internal pump bypass circuit. Vaporization can also be produced by a variety of other conditions, such as a clogged strainer or any other restriction in the line before the meter, or improper selection or installation of piping and valves, and can be aggravated by high ambient temperature or a low liquid level in the storage tank.

Many of these factors can be controlled to some degree, but some quantity of vapor is likely to be produced under certain conditions in any system, no matter how well designed and installed. The vapor eliminator is the last line of defense against metering vapor. Figure 3-6 illustrates the operation of a typical vapor eliminator.

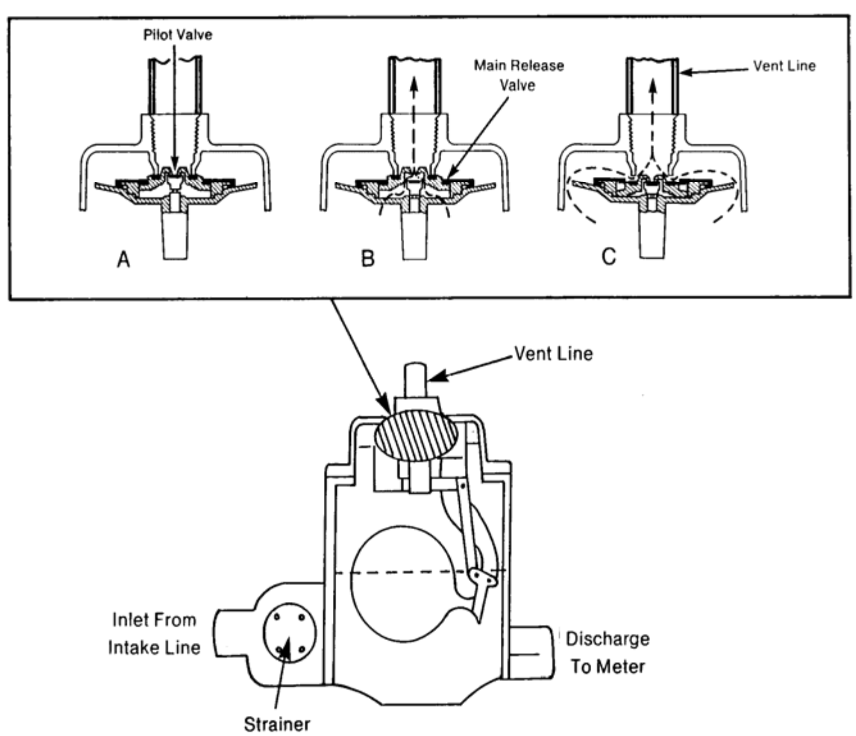


Figure 3-6. Typical vapor eliminator.

Liquid flows into the chamber, which permits separation of vapor from the liquid flow. Vapor bubbles rise to the surface of the liquid and are trapped between the liquid surface and the vent line release valve. The function of the release valve is to assure that liquid does not circulate through the vapor system when the separating chamber is full of liquid.

The release valve shown in the inset panels of Figure 3-6 is two-staged. Panel A shows the valve in its closed position, preventing vapor in the chamber below from entering the vent line. When the liquid level in the chamber falls due to a lack of product or large amounts of vapor, it lowers the level of a float (see main drawing). When the float reaches a certain level, a linkage pulls open a pilot valve, permitting some vapor to escape into the vent line (Panel B). Pressure is thus bled from the chamber, permitting the main valve to be pushed open (Panel C). This allows an even larger quantity of vapor to enter the vent line. As vapor is removed from the chamber, the liquid level again rises, raising the float, which eventually closes the pilot valve. Rising pressure on the bottom of the main release valve then seats it.

This design performs its function of removing even relatively large quantities of unentrained vapor from the product flow quite effectively. However, entrained vapor is very difficult to exclude and may pass through the vapor eliminator and into the meter.

Strainers

Two other components of the intake line pictured in Figure 3-1 are worth noting. First, you will notice that strainers are installed in the liquid line before the pump and in the inlet to the vapor eliminator. These serve to trap solid contaminants that could cause damage to the meter or pump if they were drawn in with liquid product. The strainers are removable and should be checked periodically. A clogged strainer will restrict flow, producing a pressure differential that can result in vapor production.

Valves

Reference to maintenance brings us to the second item. You will notice that manual ball-type valves are installed at a number of points in the intake line (most manufacturers recommend ball valves over gate-type valves). The purpose of these valves is to permit the liquid line to be shut off at various points so that service can be performed on a particular component. These service valves (also called line valves) are used to isolate a portion of the line, which can then be bled down and opened. The lines before and ahead of the closed valves remain full of pressurized liquid. Service valves can also be used in emergency situations to shut off the supply of liquid to a segment of hose or piping in which a rupture has occurred.

These service valves must be in their full open position while the system is in operation or they may restrict flow. Because they are used to isolate pressurized liquid product, National Fire Protection Association (NFPA) codes require that any portion of the system that can be closed off in this way must be equipped with a pressure relief valve. Handbook 44 requires that any service valves installed in the discharge line be designed in such a way that they cannot be used to divert metered product and thereby facilitate fraud (see Chapter 6 for details).

The Meter and Indicating and Recording Elements

Liquid product, as free as possible of vapor, passes from the vapor eliminator chamber directly into the meter. The meters employed in most LPG liquid-measuring systems are of the positive-displacement type, which is the same reliable and highly accurate method of measuring the volume of a flowing liquid that is used for other liquid-measuring devices, such as gasoline pumps and vehicle-tank meters. You may also find other designs of meters such as turbine and mass flow meters used in these applications. The design of positive displacement meters is, from an engineering point of view, quite sophisticated, but their principle of operation is straightforward. The diagrams of several designs shown in Figures 3-7, 3-8, and 3-9 illustrate this principle.

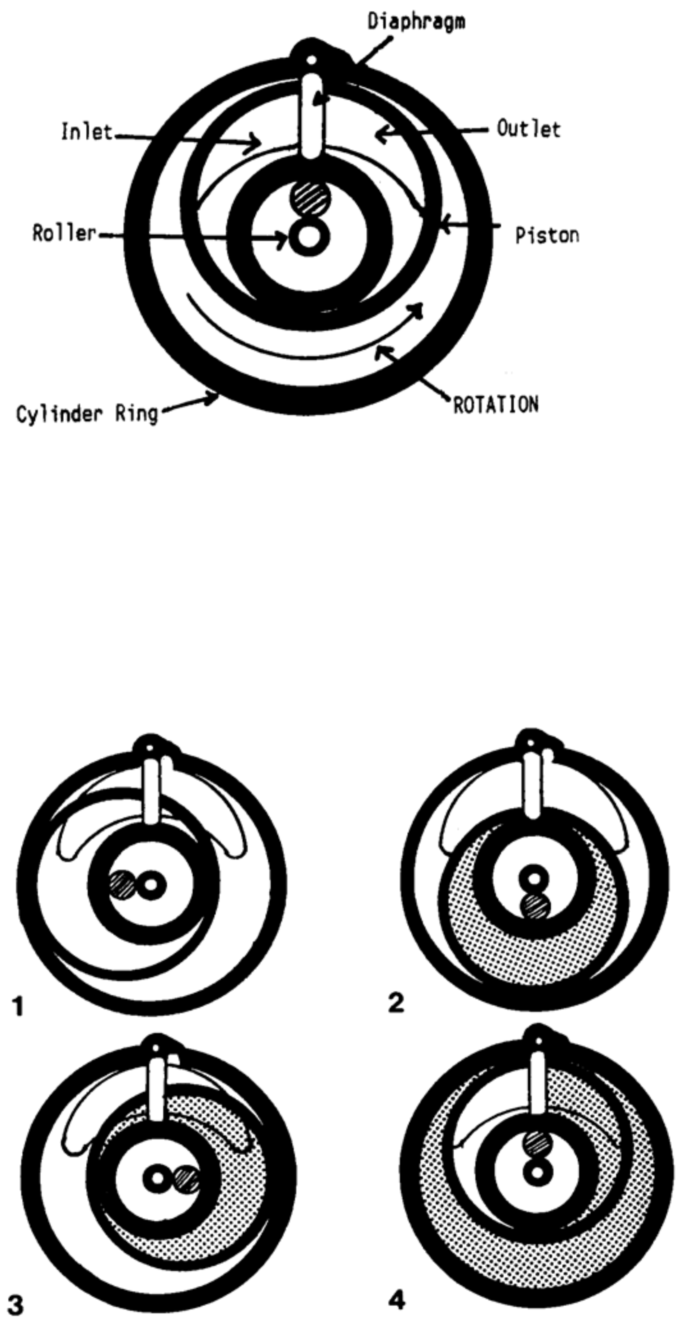
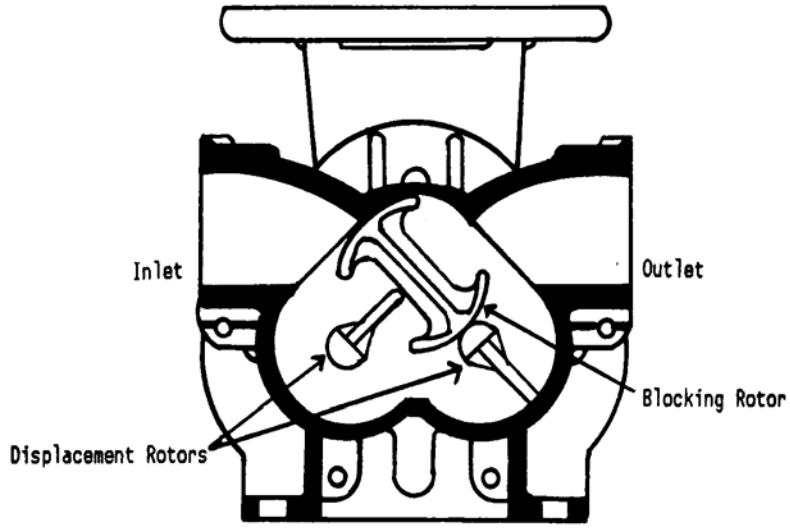


Figure 3-7. Principle of operation of one type of positive-displacement meters.



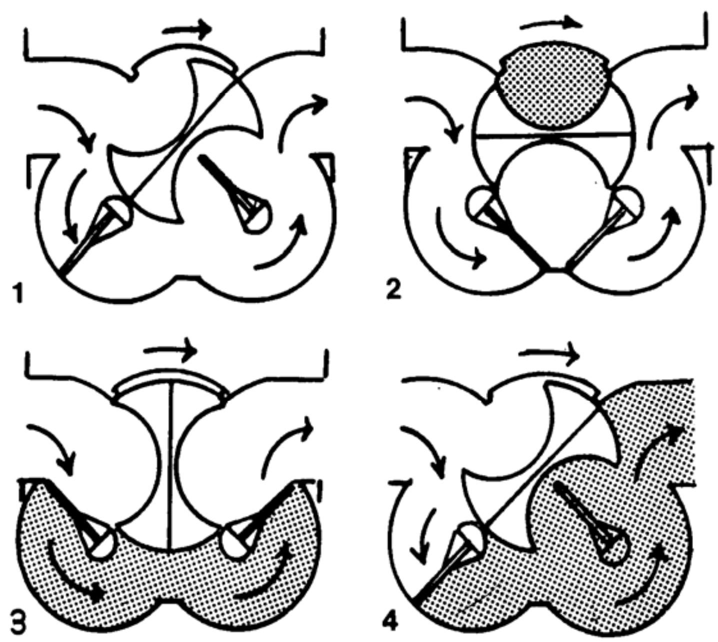


Figure 3-8. Principle of operation of one type of positive-displacement meter.

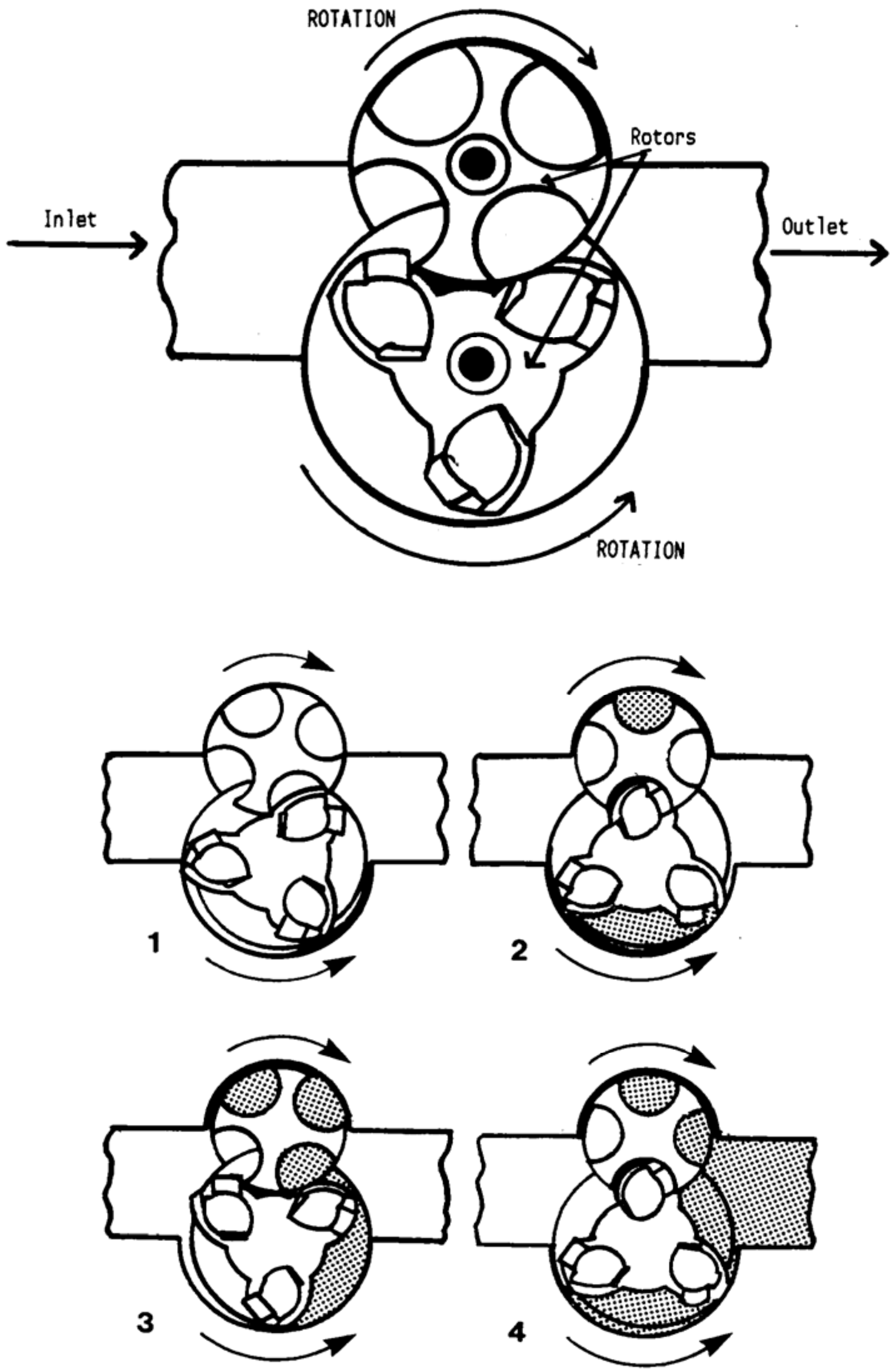


Figure 3-9. Principle of operation of one type of positive-displacement meter.

Liquid product flowing through an enclosed space -- the meter chamber -- is momentarily separated into segments of known volume. The segments are then rejoined and flow from the meter into the discharge line. The meter cycles depicted in Figures 3-7, 3-8, and 3-9 illustrate this principle. In each figure the product that has been segmented is represented by darker shading.

Fluid flow drives the moving parts of the meter. As you can see in the various drawings, the meter cycle is designed so that discharge is continuous; while one portion of liquid is being segmented, product ahead of it is simultaneously being displaced into the discharge line. Since the exact volume of each segment -- enclosed between the segmenting elements and the walls of the measuring chamber -- is known, and the same number of segments pass through the meter during each revolution, the exact volume of liquid that has passed through the meter can be determined from the number of revolutions of the meter. A shaft attached through the center of a rotating element of the meter and at right angles to it transfers the mechanical movement of the meter directly to the system's indicating elements.

Several different proprietary designs of positive-displacement meters are in common use for LPG liquid-measuring systems, including the designs depicted in Figures 3-7, 3-8, and 3-9. Because of the simple design of such measuring devices, the number of factors that commonly cause inaccurate measurement are relatively few. One, of course, is the presence of vapor in the product flow as it passes through the meter. This will cause the meter to register more liquid product than has actually been delivered.

Meter inaccuracy can also be caused by solid contaminants that are drawn into the meter where they can interfere with the free movement of the rotor and segmenting elements, or the contaminants can score the machined and highly polished surfaces of the bores of the chamber in which the segmenting elements move. This will have the effect of widening clearances, allowing a small amount of product to slip through them. Any such slippage will tend to make the meter under-register, that is, indicate less volume of liquid product than has actually been delivered. This underscores the important function of the strainer and the need for its proper maintenance.

A very small amount of slippage that occurs under normal operating conditions can be effectively offset by adjustment of the registering element (see below). However, the rate of slippage is likely to increase at low discharge rates. If the meter is relatively new, this increase in the rate of slippage at low flow rates will be insignificant from the point of view of measurement error. However, as the meter wears, clearances tend to widen somewhat, and slippage at low flow rates is aggravated. When the resultant deterioration in accuracy indicates that a meter is badly worn (see Chapter 7 for a description of how this is determined by testing), adjustment to the registering elements will no longer be adequate, and the meter will have to be removed from the system and reconditioned or replaced.

Unlike piston-type meters such as those commonly used in gasoline pumps, in which the stroke of the piston can be changed by adjusting its throw, adjustments to the quantity of product passed through a rotary meter in one revolution cannot be made. For this reason, adjustments to bring the meter as close as possible to zero error are usually made through the registering element.

The function of the registering element is to “count” the number of revolutions made by the meter during a delivery, “compute” from this count the total volume delivered, and “indicate” the quantity in a manner that is clear and readable. These operations can be performed either mechanically or electronically, as we will see. In either case the register is linked to the revolving meter shaft.

The mechanical register used on many LPG liquid-measuring systems incorporates a wheel-type indicator, the type that may be familiar to you from other types of metering devices. (In fact, the register used may be the same as that installed on fuel oil trucks or loading racks.) Figure 3-10 shows what a typical mechanical register looks like from the outside.

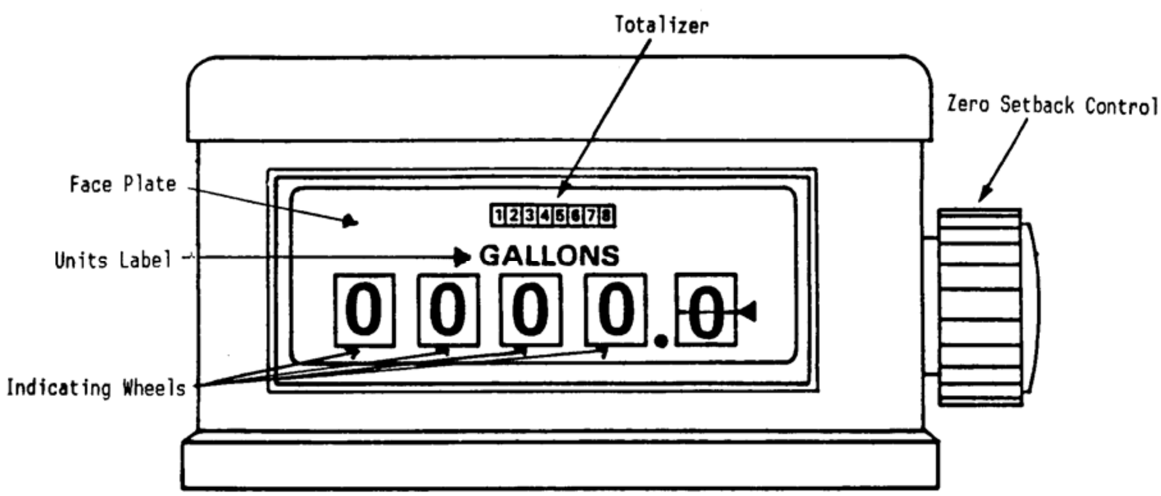


Figure 3-10. Mechanical register.

Inside the register, the mechanical motion of the revolving meter shaft is transferred through a gear train directly to a revolving wheel, like the one shown in Figure 3-11. This will be the right-hand indicating wheel on the register (in Figure 3-10, the wheel that indicates tenths of a gallon of product delivered). The circumference of the wheel is divided into equal segments (usually 10) and marked with graduation lines and number values.

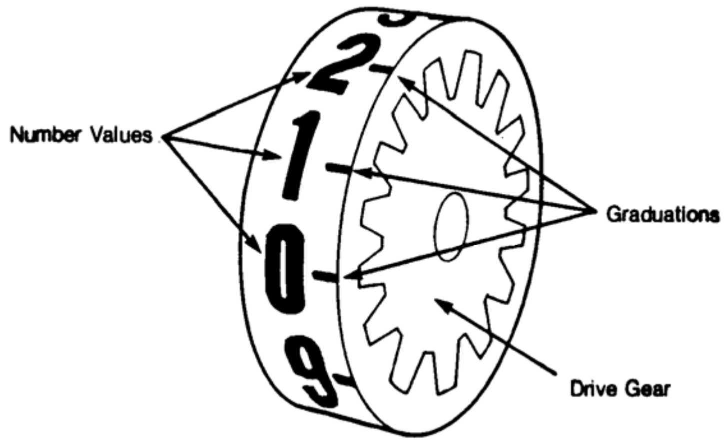


Figure 3-11. Right-hand indicating wheel.

The right-hand indicating wheel thus turns in correspondence with the revolution of the meter shaft. As you can see by reviewing Figure 3-10, only a portion of the wheel's circumference is visible at any time through a window in the register faceplate or cover plate. A fixed indicator, usually a pointer attached to the cover plate, is used to read the quantity represented by the numbered divisions or, if the indicator stops between graduation marks, a quantity intermediate between the values associated with those graduations.

A complete revolution of this indicating wheel represents a unit of delivery (in the example, one gallon). Toward the end of each revolution, the wheel turns a transfer gear that causes the wheel immediately to its left to move through one tenth of its circumference, thereby displaying its next higher number value. This process is repeated for two or more identical wheels, each turned through one tenth of its circumference by a single complete revolution of the wheel immediately to its right. Together, the wheels represent the digits of a number; the values represented by each wheel are ten times the values of the wheel to its right. This design permits relatively large values (the example in Figure 3-10 can register quantities of up to 9,999.9 gallons) to be read directly and accurately without requiring a large number of graduated scale divisions.

More and more new systems are being equipped with electronic registers, which incorporate fewer moving parts and offer additional features, such as data communication to and from remote devices, multiple-point calibration (see below), full computing capability including one or more tax formulas, and many other features that make them attractive in a marketplace that is evolving rapidly with changes in technology.

An example of an electronic register, capable of many additional functions, is illustrated in Figure 3-12. Like a mechanical register, an electronic register also produces its indication directly from the revolution of the meter shaft. However, in an electronic register, the mechanical motion is transformed into digital signals. This is accomplished by means of a device called a pulser. Several different designs of pulsers are in use, some employing optical devices, but essentially the pulser is simply a switch that is actuated a fixed number of times by each complete revolution of the meter shaft. The switch is connected to a low-voltage power supply: while it is closed a current flows through the circuit; while it is open, the current is discontinued. The result, for any full or partial revolution of the meter shaft, is a series of discrete pulses, as illustrated in Figure 3-13.

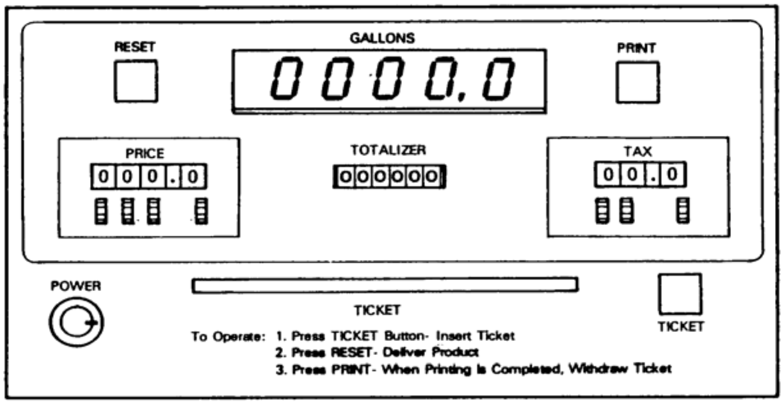


Figure 3-12. Electronic register.

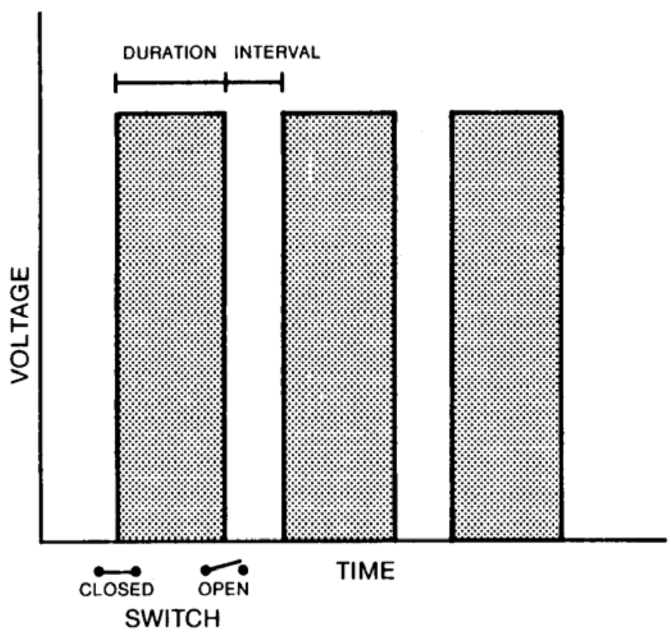


Figure 3-13. Discrete pulses.

Pulsers installed in LPG liquid-measuring systems produce from 10 to 1,000 discrete pulses per revolution of the meter shaft, depending upon the design. The pulses are transmitted to the processing circuitry of the register, which is, in fact, a small computer. This computer recognizes and "counts" the pulses electronically as they are transmitted. The circuitry then produces its own signals, which in turn drive a digital display.

As you may be aware, the requirements established in Handbook 44 for mechanical and electronic registers differ in some respects. These differences reflect, for the most part, an important distinction between two types of indicating devices; your understanding of the operation of these registers may help to make clear the distinction of the differences between analog and digital devices.

Most mechanical registers are analog-indicating devices. A formal definition of this type of device is provided in Handbook 44.

> **analog type.** A system of indication or recording in which values are presented as a series of graduations in combination with an indicator, or in which the most sensitive element of an indicating system moves continuously during the operation of the device.[1.10]

Figure 3-14. Definition of an analog-type device.

A mechanical register like the one described above meets both parts of this definition. You have seen how values are presented as a series of graduations on the right-hand indicating wheel, with a fixed indicator (the pointer) used in combination with the graduations, to effect a reading. In addition, the right-hand wheel is the most sensitive element of the system, since it indicates the smallest quantities, and this most sensitive element moves continuously during the operation of the device. As it moves, and one graduation after the next passes by the pointer, an infinite number of values intermediate between the graduated values are displayed (even though our ability to read these values is limited).

Now let us look at the formal definition of a digital-indicating device:

> **digital type.** A system of indication or recording of the selector type or one that advances intermittently in which all values are presented digitally, or in numbers. In a digital indicating or recording element, or in digital representation, there are no graduations.[1.10]

Figure 3-15. Definition of a digital-type device.

Of course, there are no graduations on a digital register display, only the numbers themselves. Furthermore, in contrast to an analog register, whose indications pass through an infinite number of intermediate values between graduations, the digital display “jumps” from one value to the next in increments.

To see how this can make a difference, first consider the indicators shown in Figure 3-16. They look quite similar and indicate exactly the same quantity, 100.0 gallons. The indicator on the left represents an analog indicator; the one on the right, a digital indicator.

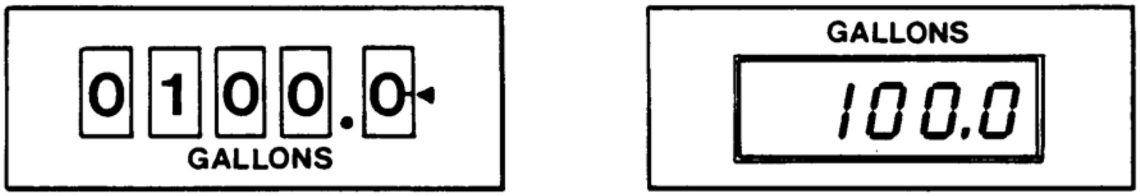


Figure 3-16. Analog and digital indicators (I).

Now imagine that we deliver exactly the same small quantity of product from both systems. The indicators then appear as in Figure 3-17.

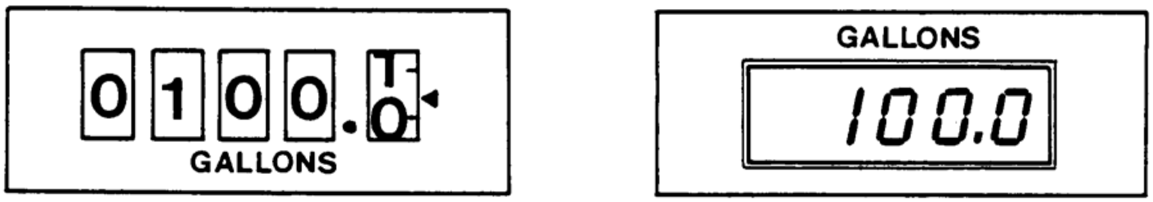


Figure 3-17. Analog and digital indicators (II).

It is clear from the reading of the mechanical indicator on the left that some product has been delivered. We can see at a glance that slightly less than 0.05 gallon has been added to the earlier reading of 100.0 gal, and by subdividing the interval on the right-hand wheel visually we can arrive at an approximate reading of 100.04 gal. The digital indicator on the right, however, still reads 100.0 gal despite the additional delivery of product and will continue to do so until about 0.01 gal more has been delivered. The reason for this is that, like most digital indicators, it is designed to "round up" to the next higher value halfway between two consecutive values.

From this example, it might seem that an analog registration system is capable of providing more accurate readings than a digital system. However, many electronic registers indicate in units of hundredths of a gallon, and some can be programmed to register thousandths of a gallon. In fact, the sensitivity of an indicating device is a function of its design: analog and digital devices are equally capable of being designed to meet the sensitivity required for their application.

Handbook 44 requires that all registers installed with LPG liquid-measuring systems that are used as the basis for retail commercial transactions must be equipped with means of resetting their indications to zero between deliveries of product. The reason for this requirement will be described more fully in Chapter 6. On a mechanical register, the reset or zero setback control is usually a lever or a knob located on the side of the register unit (as on the register shown in Figure 3-10). Operating the control all the way to its stop will turn the indicating wheels forward until they are all in a definite zero position. The reset control on an electronic register is usually a pushbutton which, when pressed, clears the display (see Figure 3-12).

In addition, Handbook 44 requires that some effective means be provided to prevent the device from displaying <u>any</u> readable indication during the course of the resetting process (again, see Chapter 6 for details). Most mechanical registers are equipped with shutters that cover the indicating wheels while they are in motion during the resetting process, obscuring any possible reading until the zero indication has been reached. On electronic registers, the display is normally blanked out completely while the circuits are being cleared and reset.

Most registers are also equipped with accumulative indicators, more commonly referred to as <u>totalizers</u>. These mechanical displays (which are visible on the registers shown in Figures 3-10 and 3-12) are generally used by the owner or operator of the device to monitor sales and inventory and to provide a means of detecting pilfering by employees.

Adjustments

As mentioned earlier, when an LPG liquid-measuring system must be adjusted to bring its registration as close as possible to zero error, it is the register rather than the meter that is directly affected by the change. Unless it is reconditioned, the meter will continue to process the same amount of product per complete revolution at a given discharge rate; the register is instead adjusted to bring the <u>indication</u> of the delivery as close as possible to a zero-error condition.

Mechanical registers are adjusted by means of a mechanism that alters the rate of revolution of the indicating wheel relative to the revolution of the meter shaft. In some models, this is accomplished by actually changing the gears that are located between the meter and the register. Such an adjustment mechanism is called, appropriately, a “change gear” mechanism. In this type of device, adjustments are made in increments or steps so that a single calibrated unit of adjustment will produce a predictable change in the indication per gallon metered. For example, an adjustor might be designed to make adjustments in increments of 0.15 percent. That means that for each unit of adjustment made, the output shaft of the adjustor will rotate 0.15 percent faster or slower (depending on the direction of the adjustment) than the input shaft from the meter; the result of one unit of adjustment will therefore be a change of 0.15 gallon (34.65 cubic inches) in registration for a delivery of 100 gallons. If the metering system is properly designed, installed, and operated, and is not badly worn, an adjustor with this degree of sensitivity would be capable of maintaining meter accuracy within weights and measures tolerances (the most stringent of which is 139 cubic inches for a 100-gallon draft).

Another design of meter adjustor allows continuous variation of adjustment over a range of values. For example, it might be capable of infinitely variable adjustment over a range of 5 percent. The speed of the output shaft to the register could thus be adjusted slower or faster by any amount within that range. This type of adjustor is equipped with a calibrated dial or some other means to allow the operator to see how much adjustment is being made. This design is also capable of maintaining meter accuracy within weights and measures tolerance if the meter is in good condition and the system is installed and operated correctly.

Mechanical adjustors are located between the meter and the register. In some models access to the adjustor is gained by removing the top of the register. In others, the adjustor is located in an assembly that is accessible by removing a cover plate on the front of the meter. In any case, either the adjustor or access to it must be protected by a security seal to prevent tampering.

As you might expect, adjustment of electronic registers is performed electronically. The operator or serviceperson determines a calibration factor based upon the errors observed during tests. This factor is keyed into the system circuitry and subsequently corrects all registered quantities by computation. Some electronic registers can also be programmed for "multi-point" calibration. This permits different correction factors to be entered for different flow rates and provides great precision if used correctly. The switches, dials, or other controls that are used to set the calibration factor are usually located behind a removable panel on the back or on a side of the register. Access to this panel and the calibration controls must also be protected by a security seal or audit trail.

As said above, a meter can only be adjusted effectively when its errors are reasonably consistent for its full range of operating characteristics. A meter that is excessively worn may register erratically, and its inaccuracy will vary at different delivery rates. The adjustor can thus be considered as a fine-tuning adjustment for a meter that is not badly worn or damaged. At some point, however, the adjustment mechanism will no longer be capable of correcting registration to within acceptable limits of inaccuracy. The topic of meter wear and adjustment will be discussed further in Chapter 7.

Recording Elements

Handbook 44 does not require that *stationary* LPG liquid-measuring systems be equipped to provide a permanent printed record of transactions. However, User Requirement 2.6 in Handbook 44 (Figure 3-18) requires LPG *vehicle-mounted* metering systems to be equipped with a ticket printer and requires the user of the device to leave a copy of the ticket with the customer.

> **UR.2.6. Ticket Printer; Customer Ticket.** - Vehicle-mounted metering systems shall be equipped with a ticket printer. The ticket printer shall be used for all sales; a copy of the ticket issued by the device shall be left with the customer at the time of delivery.
> (Added 1992)

Figure 3-18. User Requirement.

The requirement for printers on vehicle-mounted metering systems was added in 1992 and applied nonretroactively as of January 1, 1993; on January 1, 1994 the requirement became retroactive and now applies to all newly installed and existing LPG vehicle-tank meters. In addition, some States and a number of local jurisdictions require a printed ticket for all retail sales. Whether required or not, many operators make use of ticket printers because they reduce the time required to complete a transaction and eliminate errors resulting from the incorrect reading of register indications and errors in transcription or arithmetic.

If a ticket printer is installed (as on the register illustrated in Figure 3-13), it is driven directly by the register, either mechanically or electronically. Electronic registers that have price computing capability may also operate with compatible printers to produce a complete invoice, recording, in addition to the quantity delivered, the unit price of the product, the applicable tax, the total sale price, and other useful information, such as the date and time of the delivery. Specific requirements relating to the design and performance of ticket printers are described in Chapters 6 and 7.

Temperature Compensation

LPG products have high coefficients of thermal expansion (liquid propane expands approximately 1 percent in volume for every increase in temperature of 6 °F). Shrinkage of product during the winter months, especially in northern climates, can have a significant cumulative effect on inventories since the same weight of product will be registered as a lower volume when it is cold than when it is hot. To allow for stable pricing, many suppliers customarily correct the volume of product to its volume at a reference standard temperature of 60 °F to compensate for product shrinkage or expansion. If a wholesale or retail seller of LPG buys "compensated" product, it will be very much in his or her interest to perform the same correction in order to maintain competitive seasonal prices. The practice of temperature compensation is widespread throughout the LPG industry, especially in northern States.

Uniform Method of Sale of Commodities Regulation Requires Automatic Temperature Compensation

Handbook 44 does not require an LPG meter to be equipped with automatic temperature compensation, however; if your jurisdiction has adopted the Uniform Method of Sale of Commodities Regulation in NIST Handbook 130, you should refer to Section 2.21. Liquefied Petroleum Gas (Figure 3-19). This section, which went into effect on January 1, 1987, requires all metered sales from devices that deliver more than 20 gallons a minute to be automatically temperature compensated.

> **2.21. Liquefied Petroleum Gas. -** All liquefied petroleum gases, including but not limited to propane, butane, and mixtures thereof, shall be kept, offered, exposed for sale, or sold by the pound, metered cubic foot of vapor (defined as 1 cu ft at 60 ^{o}F), or the gallon (defined as 231 cu in at 60 ^{o}F). All metered sales by the gallon, except those using meters with a maximum rated capacity of 20 gallons per minute or less, shall be accomplished by use of a meter and device that automatically compensates for temperature.
> (Added 1986)

Figure 3-19. Liquefied Petroleum Gas.

Manual Compensation

If your jurisdiction has not adopted the Uniform Method of Sale Regulation, but requires or permits temperature compensation, it can also be performed manually by the operator of a device if the temperature of the product as it passes through the meter is known, by consulting appropriate temperature correction tables. However, manual computations are time-consuming and subject to errors due to faulty thermometers, inaccurate reading by the operator, transcription errors, and arithmetic errors. As a result, most sellers of LPG now use automatic temperature compensators

(ATC's) to perform the correction during the delivery. An ATC is basically an automatic adjustor, and the design of its adjustment mechanism, whether mechanical or electronic, is similar to the manual adjustors described above. Product temperature is sensed by a device installed in the meter or intake line and transmitted to the ATC.

The automatic temperature compensator (if the system is equipped with one) is usually located between the meter and the register in the "stack" (the expression used to refer to the succession of accessory registration devices that are normally installed one atop the other above the meter: ATC, register, printer). A "meter stack" is illustrated in Figure 3-20.

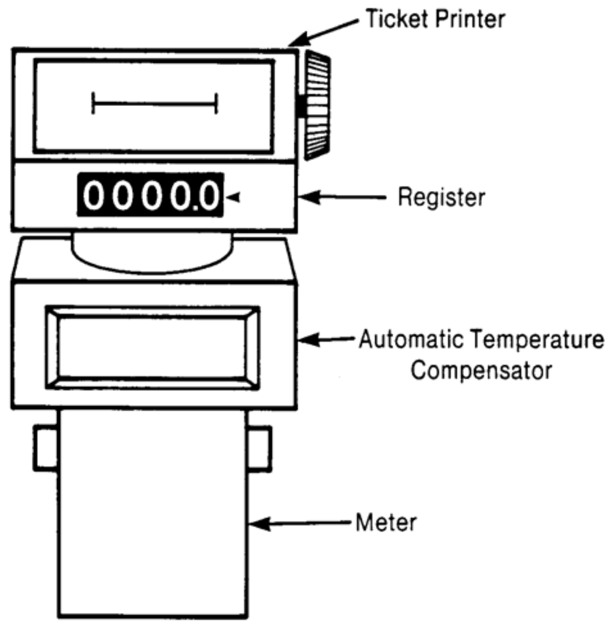


Figure 3-20. A meter "stack."

An ATC is usually equipped with a "lock-out" mechanism or some other means of deactivating it. This mechanism is necessary for testing and calibration, but should be sealed to prevent unauthorized deactivation (which is prohibited by Handbook 44 requirements and most State laws). The ATC is usually calibrated at the factory for the specific gravity of the product that will be metered by the system. In some models, the operator can vary this setting if a different product is to be dispensed. If the setting can be varied, the selector should be sealed to prevent tampering that could affect measurement accuracy.

The Discharge Line

The remaining major operating elements of an LPG liquid-measuring system are all associated with the function of controlling flow of metered product to its delivery point. Just ahead of the meter outlet is the differential pressure valve (also known as the “pressure-differential valve” or “differential backpressure valve”). It serves to maintain a level of pressure “upstream” (in the meter and intake line) sufficient to minimize vaporization of product that could be drawn into the meter. Figure 3-21 illustrates the operation of a differential pressure valve. (Note: Some systems may also include a back check valve installed adjacent to the strainer to help maintain a constant pressure in the line.)

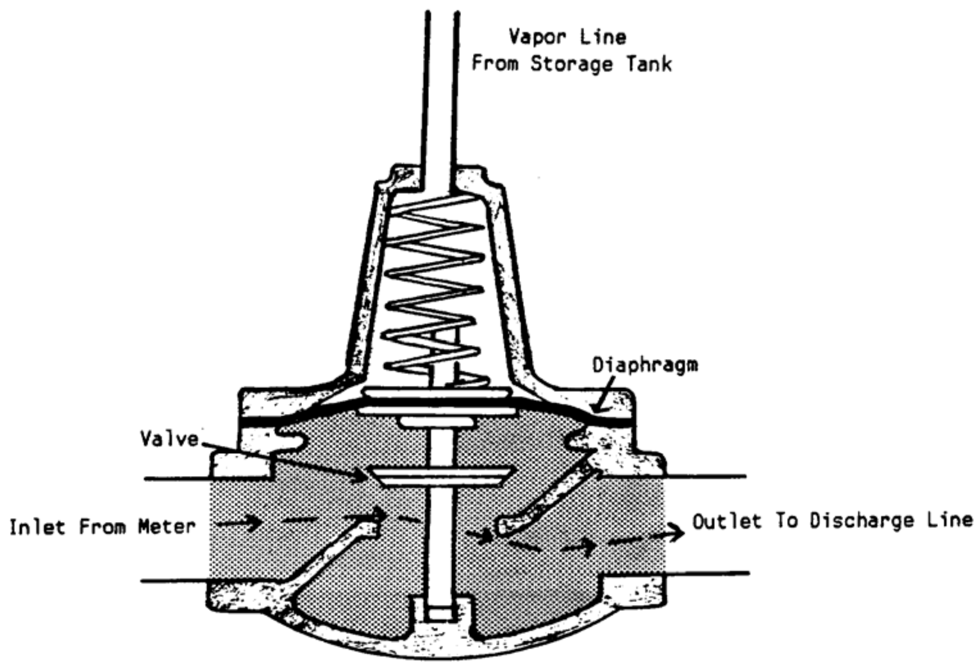


Figure 3-21. Differential pressure valve.

This automatic valve works on the principle of balanced pressure. The valve pictured has two chambers separated by a diaphragm (some models incorporate a piston rather than a diaphragm). The top chamber is connected by a vapor line to the vapor space in the storage tank. The lower chamber is filled with liquid product that has passed through the meter. When pressure on the liquid side of the diaphragm is lower than or equal to the pressure of vapor (and liquid) in the tank, a spring holds the valve closed and liquid product cannot pass into the discharge line.

If the pump is operating, pressure inside the liquid chamber will rise until it is sufficient to force the diaphragm up against the force of the spring behind it. The valve is then unseated and product flows into the discharge line.

The valve will close again when the pressure of the flowing liquid is balanced with the pressure in the storage tank. This valve assures that the pressure of liquid inside the meter behind it is at approximately the same pressure as in the storage tank.

Maintaining "back pressure" in this way increases the efficiency of the vapor eliminator and prevents pressure in the meter from being bled into the discharge line when the pump is not activated (for example, between deliveries or when the installation is closed overnight).

The discharge line or hose carries metered product to the receiving tank. In order to assure accurate measurement, the discharge line must be full of liquid product at the beginning of a delivery and under full system pressure. This is frequently referred to as a "wet" delivery hose. As a result, it must have a valve at its discharge nozzle that can be closed when delivery has been completed to prevent draining of the discharge line.

Since liquid product is trapped in the delivery hose, between the differential pressure valve and the discharge nozzle valve, the possible effects of thermal expansion must be provided for. To prevent expansion of the liquid from damaging or even rupturing the discharge hose, a pressure relief valve is necessary. This valve is similar in design to the type described earlier, except that product is vented to the storage tank rather than to the atmosphere. This is usually accomplished by running a tube from the outlet of the differential pressure valve to the vapor return line that connects the storage tank and the vapor eliminator. The pressure relief valve is installed in this tube at the point where it connects to the vent line (usually at the top of the air eliminator; see Figure 3-1).

This completes our discussion of the major operating elements of an LPG liquid-measuring system. A number of accessory components that are in common use but are optional devices not critical to the operation of most systems, and which do not affect measurement accuracy, have been omitted. You will become familiar with these accessory devices as you gain experience in the field.

Summary

A number of separate operating elements work together to assure the safe, efficient, and accurate operation of an LPG liquid-measuring system.

The intake line carries product from the storage tank to the meter; the system pump is located in the intake line, as are the vapor eliminator and several automatic and manual flow-controlling devices which serve to minimize vapor production, prevent excess-flow in the event of a leak, permit controlled venting of product to the atmosphere if internal pressure exceeds safe limits, and permit portions of the system to be isolated for service.

The meter is typically of the positive-displacement type. Indicating elements may be either mechanical or electronic, analog or digital. Meter errors are corrected by adjustments that affect the registration, not the quantity of product processed per meter cycle. Accessory devices, such as a ticket printer or automatic temperature compensator, may be incorporated in the metering unit.

The discharge line includes a differential pressure valve, which maintains upstream pressure (in the meter and intake line) at a level that helps minimize vaporization, and a discharge hose, which is equipped with a manual shutoff valve. A pressure relief valve relieves excessive pressure buildup in the discharge hose between deliveries due to thermal expansion.

Specific requirements relating to the selection, design, installation, maintenance, use, and performance of these elements are described in detail in Chapters 6 and 7.