Chapter 3

The Operation of Vehicle-Tank Metering Systems

Chapter Objectives

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

1. Identify and describe the operation of specific major elements of the vehicle-tank metering system.

2. Describe differences in design and operating characteristics of these elements in different types of systems.

3. Describe in general terms the operation of a positive-displacement metering device.

4. Understand the difference between analog and digital indicating and recording elements of vehicle-tank metering systems.

Introduction

In this chapter, we will take a closer look at each of the major operating elements of a vehicle-tank metering system. Varieties of designs are in common use, and new features are being incorporated almost continually with advancements in technology and with changes in the marketplace. In the interest of providing a thorough and comprehensible introduction, we will not cover specific features of every model available from each of the manufacturers of these components. You will acquire this specific knowledge most effectively through experience in the field. This introduction will instead focus on design features and operating characteristics that are generally significant for the range of devices you are most likely to encounter. In some cases, illustrations of particular designs are used. These are intended to help you understand typical features.

The Vehicle Tank and Intake Lines

We have already discussed the general features of the vehicle tank. In a system that is properly installed, maintained, and operated, the design and capacity of the tank will generally not affect the capability of the metering components to measure and indicate accurately.

The manifold that controls the flow of product from multiple tank compartments was also described in the last chapter. One obvious function of this component is to select which compartment will deliver product to the meter. This is accomplished by closing all compartment valves at the manifold except the one that contains the desired product. The manifold also performs another important function – to prevent air from being drawn into the system from empty compartments. When a compartment is empty, its manifold valve must be closed before delivery is resumed from another compartment. If this is not done, air can be drawn from the empty compartment through the open manifold valve and churned into the product being delivered from the other tank. The resulting quantity of air introduced into the system may then exceed the capability of the air eliminator to remove it. If this happens, air can be drawn into the meter and cause overregistration (the indicated quantity is greater than the quantity of product actually delivered).

Piping from the tank outlet (or from the manifold outlet if the tank is compartmented) carries product ahead toward the meter and, thus, can be referred to as the meter intake or supply line. It should, like the tank, be made of material that is appropriate for the product(s) it carries. It should also be installed in such a way as to be shielded from the sun and wind in order to minimize the effects of extreme outdoor temperature conditions on the product, and should have no vertical bends that could trap air or vapor. In addition, the piping should be of the correct size (inside diameter) for the meter. This is especially important in a gravity-discharge system. If gravity is drawing product through the meter and into the discharge line faster than it can be supplied by the intake line, a negative (suction) pressure condition could develop at the meter inlet. Some products that can be maintained in a liquid state under atmospheric pressure will tend to vaporize readily under relatively small negative pressure. A good example is gasoline, a typical grade of which has a vapor pressure (absolute) of about 7 pounds per square inch (psi) at 80 °F. (The vapor pressure of a product is the pressure that must be applied to maintain a contained product in its liquid state at a given temperature. The vapor pressure is unique to that product and is a function of temperature.) At ambient pressures less than its vapor pressure (atmospheric pressure is about 15 psi) gasoline will readily change to its vapor state. If the pressure at the meter inlet is less than the vapor pressure of the product (a "negative pressure" condition), vapor will accumulate at that point. If the accumulation is more than the air eliminator can handle, the vapor may be drawn into the meter, resulting in overregistration.

If the system is power operated, the pump will be located on the intake line, as shown in Figure 3-1. The pump is usually driven directly by the truck engine, through a linkage that is controlled by the operator. When the pump is engaged, it draws product from the tank and propels it toward the meter. The pump should be installed at a level slightly lower than the tank outlet (although the line should not pitch sharply at the pump) and should be matched to the size of the intake line. Again, the purpose of these measures is to minimize the effects of negative pressure conditions on product in the intake line. The pump must obviously also be capable of developing sufficient pressure in the line ahead of it to propel the product to its delivery point.

The Air Eliminator

Before we look at the operation of a typical air eliminator, let us consider why such a device is needed in the first place. Obviously, the customer does not want to be paying for air or vapor, but how do these gases get into the liquid flow?

The most common way for air to enter the system is through the tank. This is especially true if a vortex forms at the drain opening. (A vortex is what you often see when you drain a sink or bathtub: the water swirls around a column of air that is moving rapidly downward and into the drain.) It is possible to minimize this effect, which will draw large quantities of air, by installing baffle plates above the drain openings. This breaks the column of air as it forms, and so eliminates the vortex.

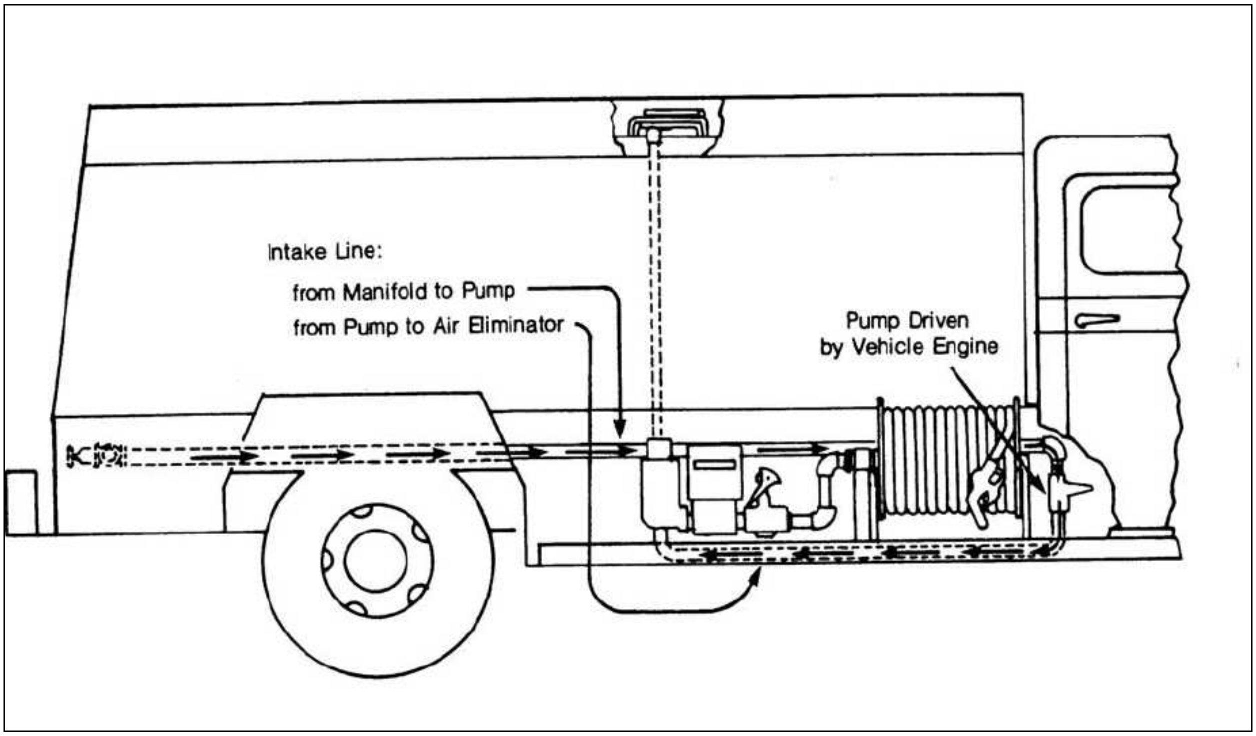


Figure 3-1. Power-Operated System

Under normal operating conditions, large quantities of air are also introduced into a system when a tank compartment is emptied. This will occur regardless of how quickly the operator detects the condition and responds by shutting off the discharge flow, disengaging the pump, or closing the manifold valve for the empty tank and opening the valve for another compartment that contains product. The intake line will fill with air almost instantly, even in a system that is in excellent operating condition. Product vapor will, of course, also be drawn into the intake line from the tank, along with the air.

The only other source of significant quantities of vapor in a system that is installed, maintained, and operated properly is the result of temperature changes in the product, usually during periods when the system is at rest. For example, on a hot summer day, the entire system, including the product, will warm gradually as the day progresses. In addition, the product is heated slightly by friction produced as it flows through the system. When the truck is parked for the night, the product filling the lines will be warm. As the ambient temperature drops overnight, the product loses heat, and as it does, it contracts and occupies less volume. The result, as the product continues to cool, is a partial vacuum in the lines. This condition encourages some vaporization. By the next morning, when the truck goes out to make its first delivery, a significant amount of vapor may have accumulated in the lines.

Air and/or vapor may also be introduced into the system as the result of improper installation or maintenance. We have already mentioned one such condition, mismatching of meter and/or pump capacities with the size of the system's piping. Air may also be drawn into the intake line through leaks in piping connections or faulty valve seals.

These are the major sources of air and vapor in the system. Since some accumulation of these gases is normal and practically unavoidable even in a properly installed, maintained, and operated system, the air eliminator is not simply a "back-up" or emergency component, but must function correctly under all operating conditions.

The air eliminator is installed at the end of the intake line, with its outlet connected directly to the meter inlet. Figure 3-2 illustrates a typical configuration.

In addition to eliminating air from the liquid flow before it enters the meter, most air eliminators are equipped with a strainer, which traps any solid particles in the product. This strainer is removable and should be cleaned as part of the regular maintenance of the system. A clogged strainer can disrupt flow, and an excessive accumulation of foreign matter in the strainer can lead to its rupture and the subsequent passage of these solid particles into the meter. This can cause serious damage to the mechanism and may also affect the accuracy of the meter.

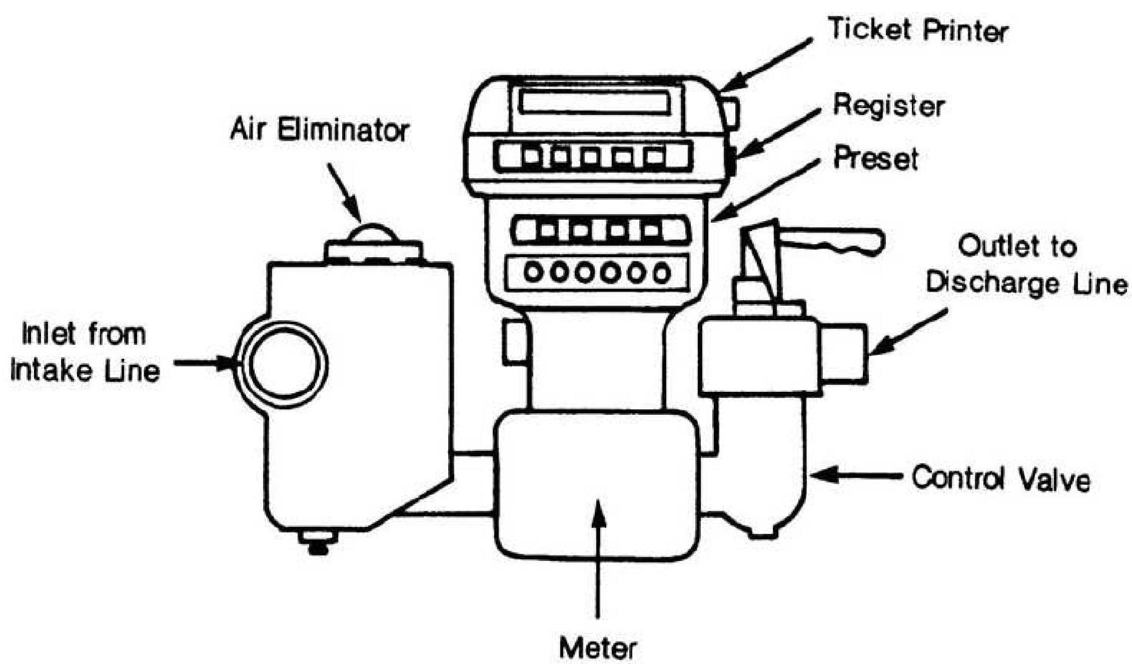


Figure 3-2. Air Eliminator and Meter Assembly

A number of different designs of air eliminators are available, but their basic principle of operation is the same. This can be seen in the cutaway of a typical air eliminator shown in Figure 3-3. Liquid product flows through the strainer (A) and fills the bottom portion of the chamber. Air and vapor that have been carried through the line rise into the upper portion and pass from the top of the chamber into a vent line (B). To prevent product from rising through the chamber and into the vent line, a valve is installed at the opening to the vent line (C). This design keeps some quantity of air/vapor in the top of the chamber at all times, and thus prevents the liquid level from rising above a certain point. This level is regulated by a float (D), which actuates the valve at the top of the chamber, generally by means of a direct linkage, as in the example shown (E). As the quantity of air/vapor trapped above the liquid increases, the liquid level lowers. This in turn lowers the float.

When the float drops to a specified level, it pulls open the valve, permitting the gases to flow into the vent line. As this happens, the liquid level rises once again, pushing air and vapor into the vent line and raising the float with it. When the float rises to a specified level again, it pushes the valve to the vent line closed, trapping the desired quantity of air/vapor behind it.

The vent valve depicted in this example is actually a two-stage valve. The first-stage valve (F) is smaller, and is actuated by the float, as described above. When this valve is opened, air/vapor escapes into the vent line, reducing pressure below the plunger (G) that is attached to the larger second-stage valve (H). Higher pressure above the plunger then forces the second-stage valve down off its seat, permitting a larger quantity of air/vapor to be expelled. When the float rises again, it closes the first-stage valve. Pressure then equalizes above and below the second-stage valve, which is then forced back onto its seat by a spring. Such a design provides a smooth opening of the valve and thus prevents an abrupt expulsion, reducing shock and wear on the mechanism.

When there is not sufficient product supply to the bottom of the chamber, as occurs when the tank or compartment is empty, the float continues to drop after the vent valve has been fully opened. When the float reaches a lower specified level, another linkage closes a valve at the outlet to the meter (I), preventing any air or vapor from being drawn through. (The example shown utilizes a butterfly valve. Other designs incorporate an air-actuated valve, which operates on the same unequal-pressure principle described above.)

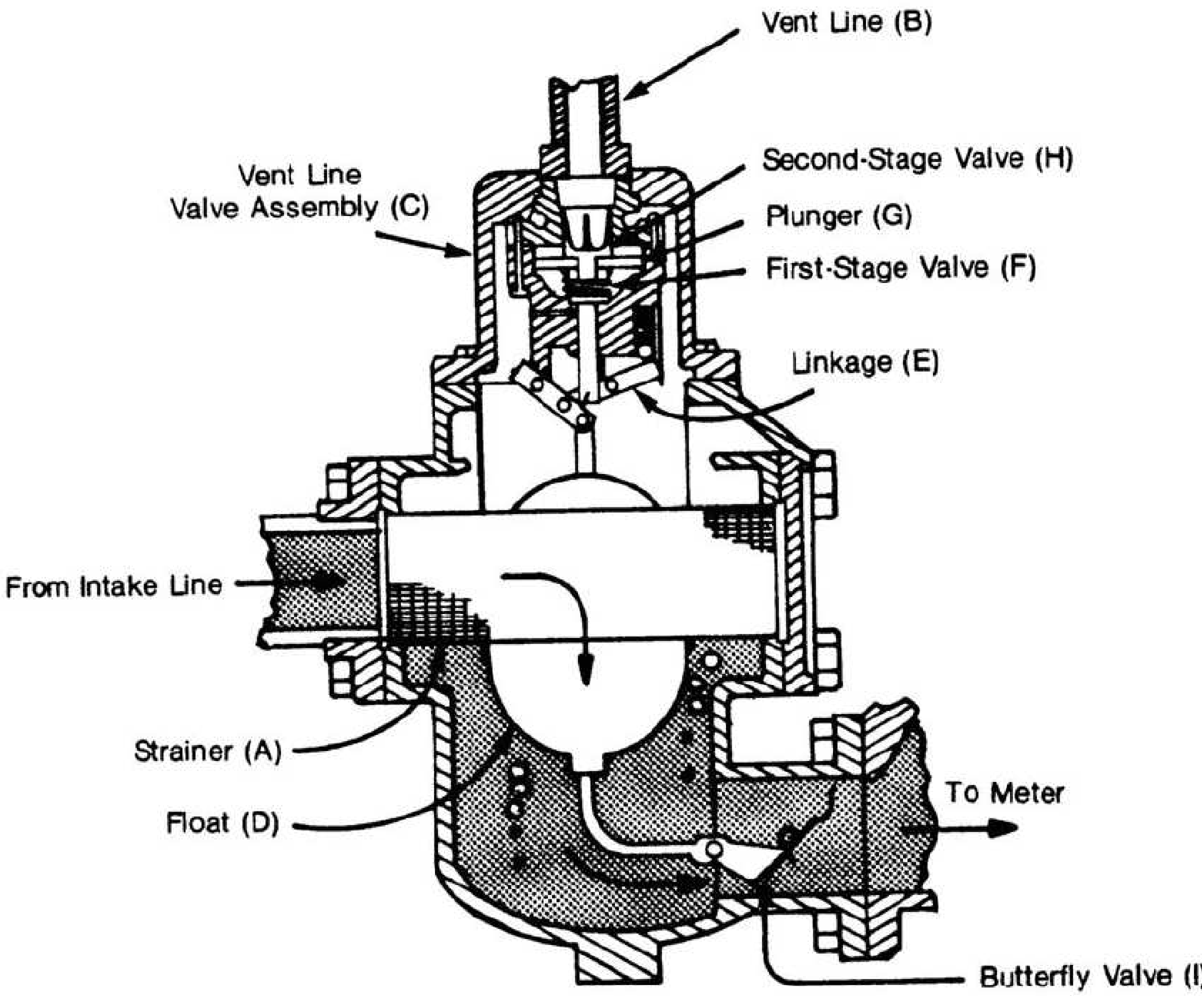


Figure 3-3. Cutaway of a Typical Air Eliminator

In a power-operated system, the vent line carries the expelled gases back to the tank, where they are vented (as shown in Figure 3-4).

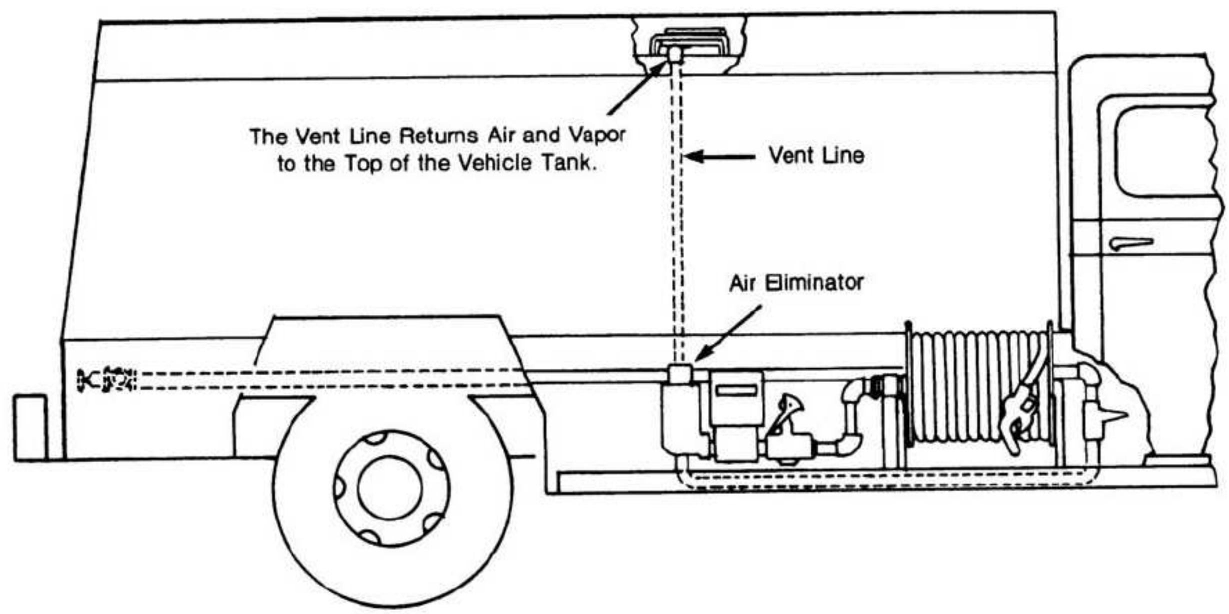


Figure 3-4. Installation of Vent Line, Power-Operated System

In a gravity-discharge system, the vented gases are generally dispersed in another way, as shown in Figure 3-5. Air and vapor are carried around the meter and vented into the discharge line. This nature of this design serves as a siphon-breaker, which is necessary (and required by Handbook 44) because the suction pressure of product in the discharge line will continue to draw upon the meter, even though there may be no product supply. The air/vapor vented into the discharge line relieves suction pressure at the meter outlet, and allows the product in the discharge line to fall into the receiving tank. This prevents the meter from being drained of liquid.

The air eliminator should be capable of preventing gases from entering the meter under normal operating circumstances, including a "split-compartment" delivery (when product is exhausted from one tank compartment and delivery is resumed from another). Its failure to perform may result from any one of several factors:

- Mechanical failure of the float mechanism, resulting from rupture of the float itself or damage to or distortion of its linkages.

- Malfunction of the air vent valve. If it will not close, liquid can rise into the vent tube, blocking the vapor passage. If the valve will not open, pressure inside the chamber will eventually force air/vapor into the meter.

- If the vent tube is obstructed, either by a crimp or by the induction of solid material, unrelieved pressure will similarly force gases into the meter.

The split-compartment delivery generally provides the most severe test of the air eliminator, since it must respond quickly to a large and rapid influx of air. An air eliminator which is worn or in need of reconditioning may function adequately under most conditions, but be incapable of responding effectively to this extreme situation.

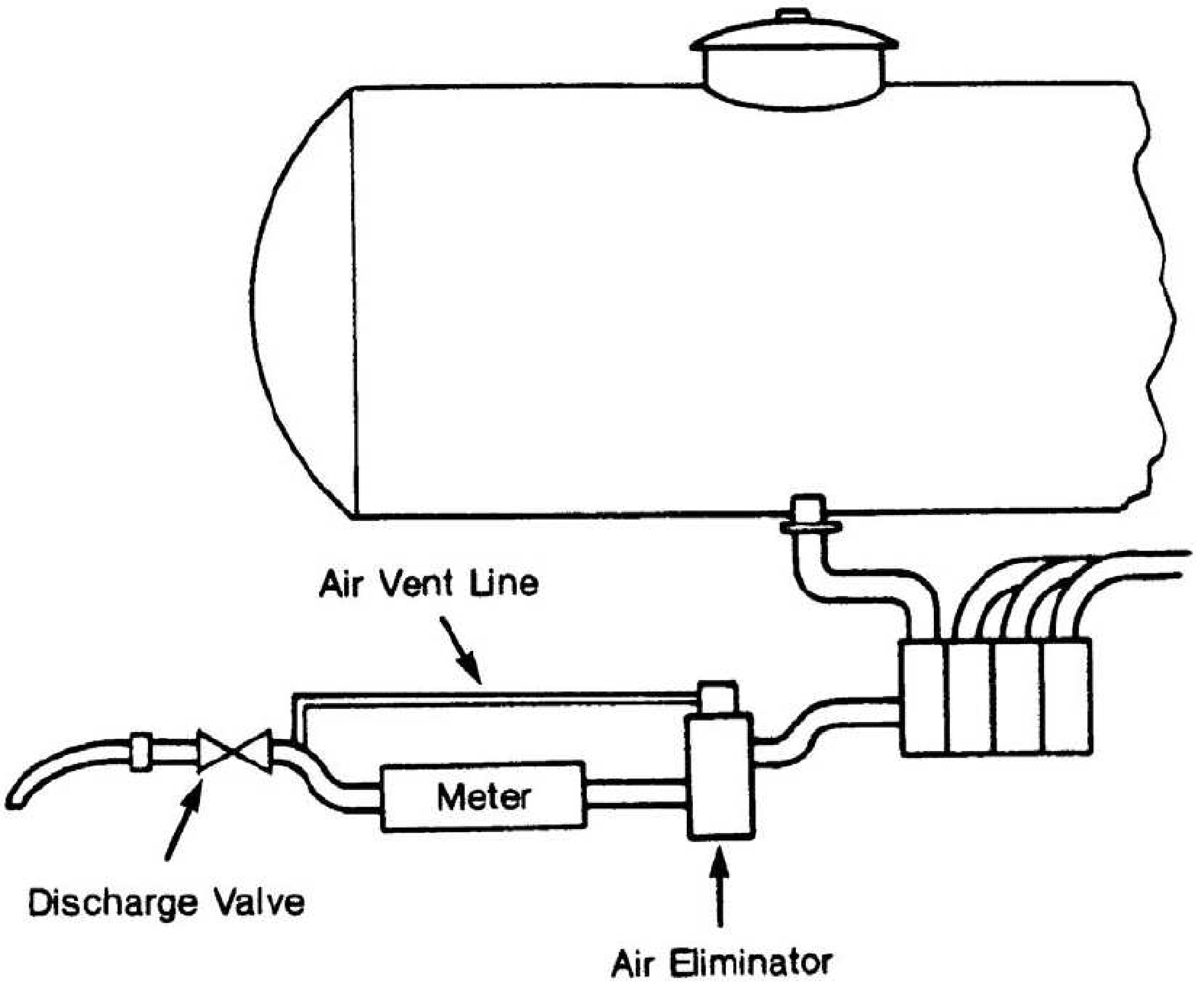


Figure 3-5. Installation of Vent Line, Gravity Discharge System

The Meter

The meter is the heart of the vehicle-tank system, capable of measuring liquid flow at rates that (depending upon the rated capacity of the meter) may exceed 300 gpm with a degree of inaccuracy of less than 0.1 % (e.g., an indicated delivery of 500 gallons of product can be no more than 500.5 gal and no less than 499.5 gal, a maximum error of no more than 2 quarts)! This amazing capability is in large part due to the positive-displacement method of metering that is employed by many modern vehicle-tank systems.

The design of these devices is, from an engineering point of view, highly sophisticated. But their principle of operation is quite simple. The cutaway diagram of a typical design in Figure 3-6 illustrates this principle. Liquid product flowing through an enclosed space – the meter chamber – is momentarily separated into segments of a known volume. The segments are then rejoined and flow from the meter into the discharge line.

In the example shown, the liquid is segmented by retractable blades (A), which are mounted on a revolving rotor (B). Fluid pressure on the blades causes the rotor to revolve at a rate that corresponds to the flow. In Stage 3, you can see that a quantity of product has been segmented by blades C and D. In Stage 4, the next quantity (E) has been segmented. Since the exact volume of each segment – enclosed between the blades, the rotor wall, and the inside walls of the chamber – is known, and since the number of segments produced in a single revolution of the rotor is known, the exact volume of liquid that passes through the chamber in a single revolution of the rotor is also known. In a typical meter, one gallon of product passes through the meter in a single revolution. The rotor is mounted on a shaft (F), which revolves with it. This revolving meter shaft drives the register (see Figure 3-6).

The example shown is a rotary-type design, a type commonly used in vehicle-tank meters. This particular example was chosen because it illustrates the principle clearly in a two-dimensional drawing. Each of the manufacturers of vehicle-tank meters has one or more of its own proprietary designs, each of which has some unique features. You can learn about these specific designs, and the claims that are made for them, by reviewing the manufacturers' literature and industry publications.

One obvious advantage of this type of design is that it requires relatively few moving parts. This minimizes friction and wear. Another common design feature reduces these factors even further. Though it is not apparent in the diagram, the elements that segment the flow – in the case of the example, the retractable blades – never actually touch the walls of the metering chamber. A small clearance – typically 0.005 inch or less – separates these surfaces when they are at the point of closest proximity.

Because of its relative simplicity of operation and few moving parts, meter malfunctions are caused by a limited number of factors. As has been mentioned, dirt or foreign matter that is drawn into the meter can cause problems if it interferes with the free movement of the rotor or segmenting elements. Solid particles can also have an abrasive effect on the machined and polished surfaces of the meter wall. This can increase friction and widen the very small clearances, allowing product to slip between opposing surfaces. (For this reason, it is especially important that the tank and supply lines of a new system be thoroughly flushed before the meter itself is installed. This will wash away filings and other loose waste metal left behind during the finishing process at the factory.)

The only other factor that is likely to affect the accurate performance of the meter is normal wear. Even a slight amount of play, especially in the moving elements that segment the flow will increase friction and slippage of product through meter clearances, causing erratic measurement. No matter how well designed, maintained, and operated, any meter will eventually require reconditioning.

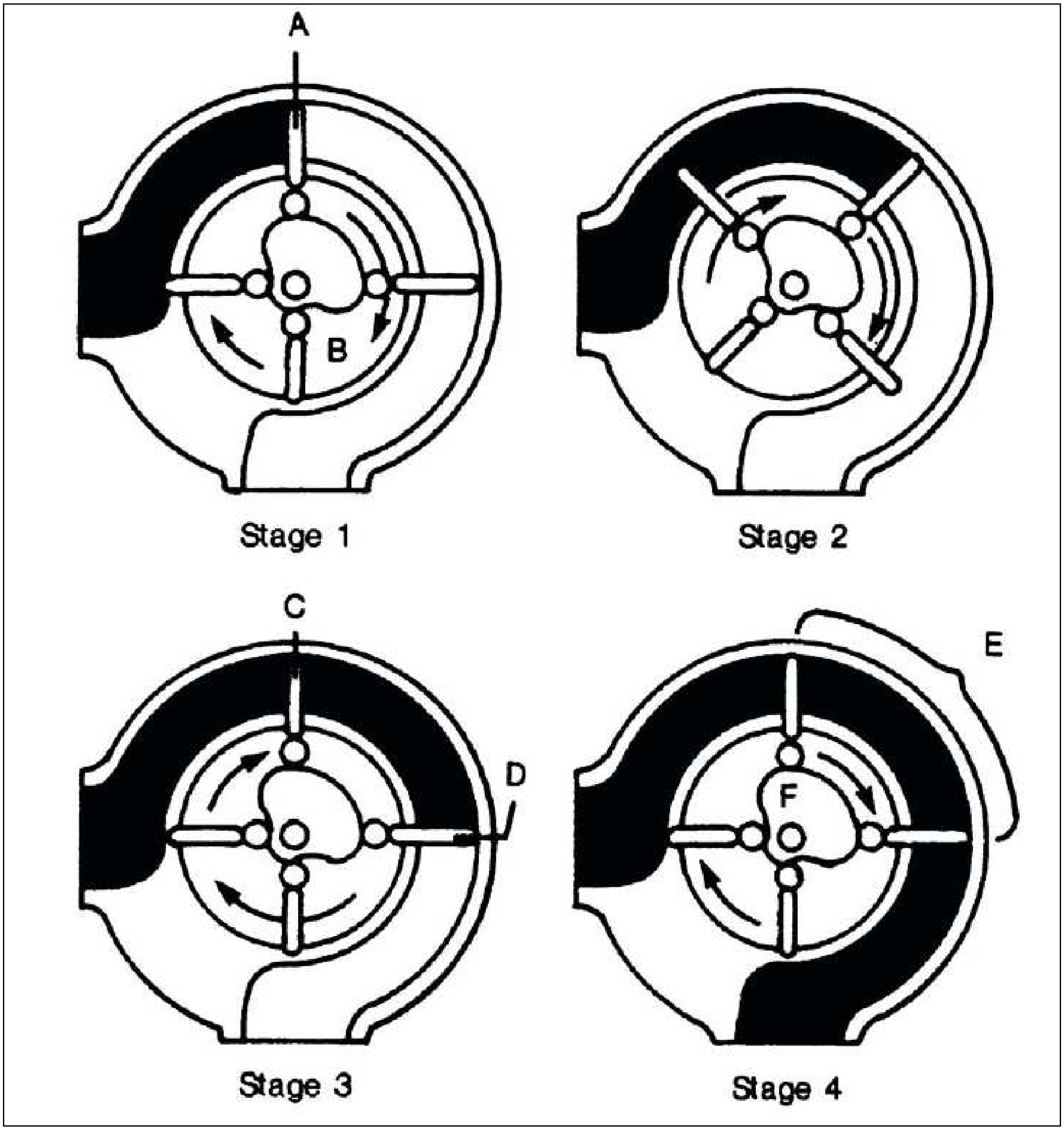


Figure 3-6. Diagram of Typical Positive-Displacement Meter

The meter itself cannot be adjusted in increments (as, for example, a gas pump meter can). The system is calibrated by adjusting the indicating element, the register. This will be discussed in the next section.

The Register

If the meter is the heart of the vehicle-tank system, the register is the brains. Its primary function is to "count" the number of revolutions made by the meter during a delivery and, on the basis of this count, to display the quantity of product that has passed through the meter. The register produces its indication directly from the revolving shaft of the meter, either mechanically or electronically.

The mechanical register used on vehicle-tank systems incorporates a wheel-type indicator, the type used on many mechanical gas pumps. The revolving meter shaft transfers its motion through a gear train directly to a revolving wheel. As you can see in Figure 3-7, graduations and number values are printed on the edge of this wheel. These markings divide the circumference of the wheel into a number of equal segments, usually ten, and show the value that each particular segment represents.

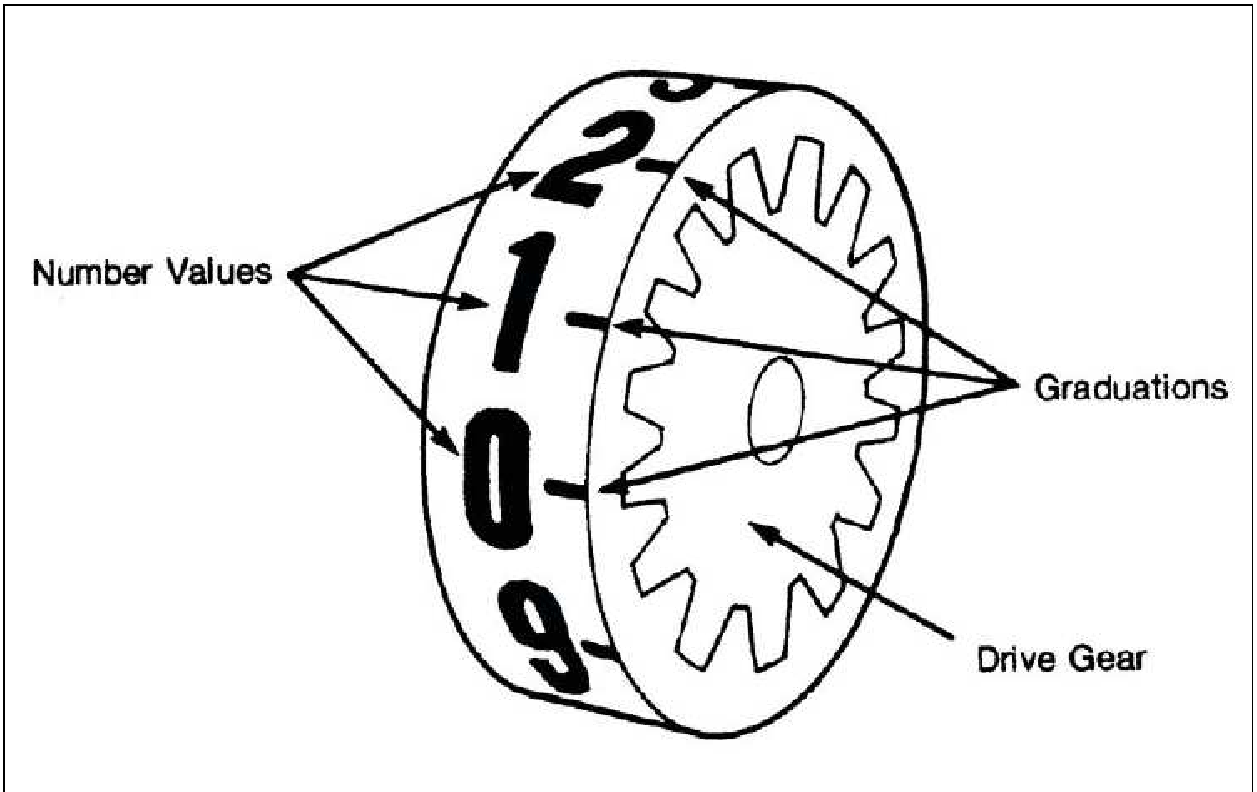


Figure 3-7. Indicating Wheel

In most vehicle-tank systems, this wheel is geared to revolve at the same speed as the meter shaft: each complete revolution represents the passage of one gallon of product through the meter. A portion of the wheel's edge is visible through a window in a cover plate, as can be seen in Figure 3-8. Attached to the side of the window is a fixed indicator (a pointer). In this example, the passage of one segment of the wheel (from the center of one graduation to the center of the next) past the pointer represents one-tenth of a gallon of product delivered.

During the latter part of each revolution, the movement of the wheel causes another wheel, located to its left and usually identical to it, to turn through one tenth of its own circumference. In the example shown in Figure 3-8, each segmented interval thus represents one gallon delivered on this wheel, and a complete revolution represents 10 gallons. This process is repeated for three more identical wheels, each turned through one tenth of its circumference by the complete revolution of the wheel to its right. Each wheel thus represents values 10 times greater than those represented by the wheel on its right: each interval for the leftmost wheel indicates one thousand gallons of product delivered.

An electronic register also produces its indication directly from the motion of the meter shaft. But in an electronic register, this mechanical motion is transformed into digital signals. This is accomplished by a component that is commonly called the pulser. The pulser generates a known number of discrete electrical pulses for each complete revolution of the meter shaft. Pulsers installed on vehicle-tank systems generate 10 to 1,000 pulses per revolution, depending upon the design.

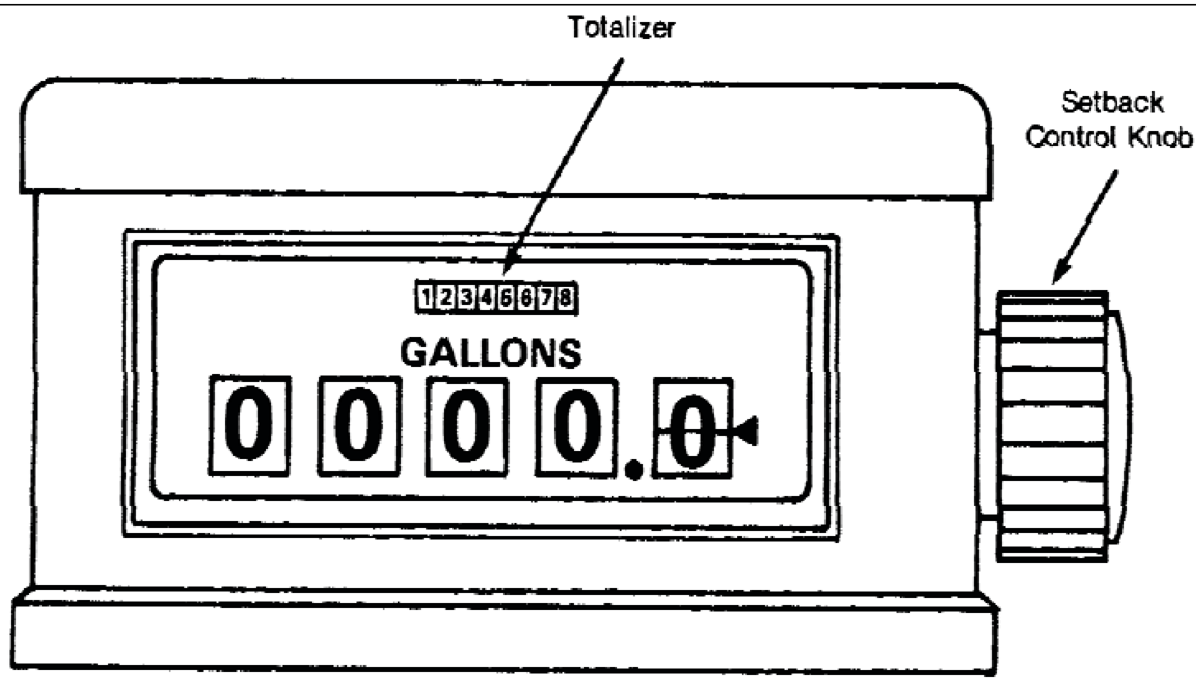


Figure 3-8. Mechanical Register

There are various types of digital signal pulsers, but most commonly, the pulser is a switch that opens and closes with the rotation of the shaft driven by the meter. Some pulsers use shaft encoders including a disc containing narrow opaque regions spaced from each other by relatively wide transparent regions. As the meter shaft rotates, light from a light source is directed through the regions toward a light detector. The output from the light detector is then a train of pulses.

The square wave output from either a switch or a shaft encoder is illustrated in Figure 3-9. It is a train of pulses which relate directly to the rotation of the meter.

The duration of individual pulses and the intervals between them will vary with the rate of rotation of the meter shaft, but their voltages will be of the same magnitude and, for the duration of each pulse, constant. These discrete pulses are transmitted to a component of the register's circuitry called the central processing unit (CPU). The CPU "recognizes" these pulses as signals, "counts" them, and computes the number of gallons on the basis of the known number of pulses per meter revolution. The CPU then sends its own signals, which activate the digital display: each signal from the CPU instructs the display to add one increment (usually 0.1 gal) to the value of its current display. An electronic register is illustrated in Figure 3-14.

As you will see when we turn our attention to field examination procedures in Chapter 5, specific requirements for mechanical and electronic registers differ in a number of respects. These differences reflect an important distinction, which your understanding of the design and operation of these devices should help make clear. This is the distinction between analog and digital devices.

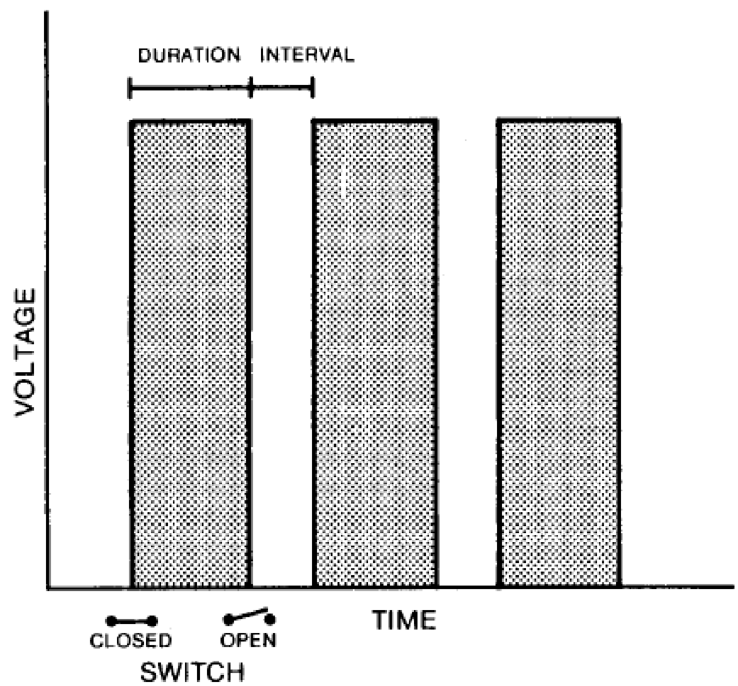


Figure 3-9. Generating Discrete Pulses

Mechanical registers are analog-type devices. A formal definition of this type 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.

Figure 3-10. Definition of "Analog Type," NIST Handbook 44 Appendix D, Definitions

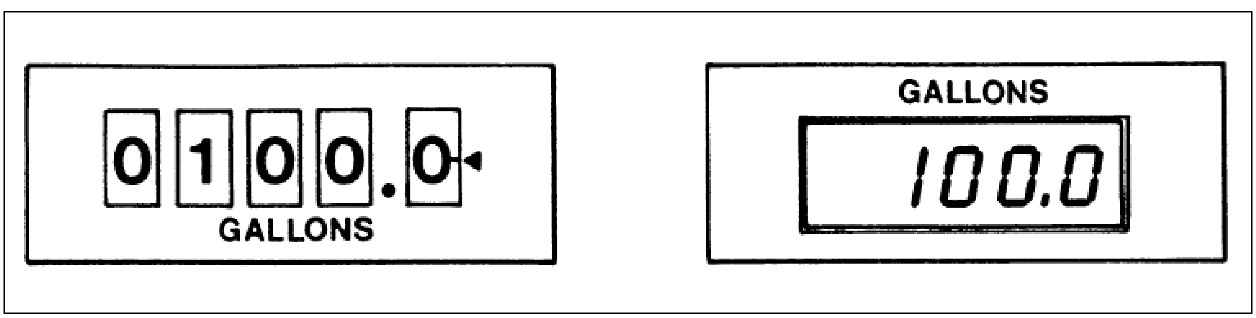
A mechanical register like the one described above meets both parts of this definition. You have seen how values are presented as a series of graduations on the indicating wheel, with an indicator (the pointer) used in combination with the graduations on the righthand wheel (in our example, the tenths-of-a-gallon wheel) to effect a reading. This righthand wheel is the most sensitive element of the indicating system, because it indicates the smallest quantities that the system is capable of representing. And this most sensitive element moves continuously during the operation of the device, driven directly by the meter shaft and gear train. As it moves, and the indicator passes from one graduation to the next, it also passes through an infinite number of intermediate values (though our ability to read these values is limited from a practical point of view). Now let us look at the formal definition of a digital device type:

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.

Figure 3-11. Definition of "Digital Type," NIST Handbook 44 Appendix D, Definitions

Of course, there are no graduations on a digital register display, only the numbers themselves. And in contrast to the analog register, whose indicator passes through an infinite number of intermediate values between graduations, the digital register indicates no intermediate values. It "jumps" from one value to the next.

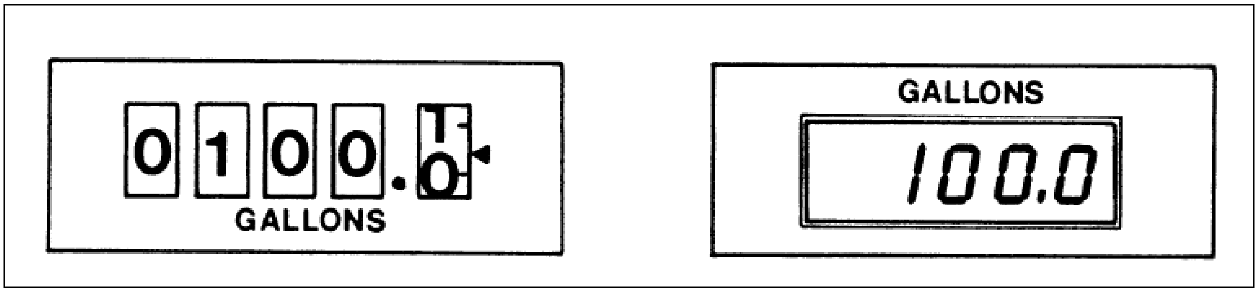
Consider the indicators depicted in Figure 3-12. They look quite similar, and in fact indicate exactly the same quantity, 100.0 gallons. The drawing on the left represents an analog indicator, that on the right a digital indicator.



Analog Indicator Digital Indicator

Figure 3-12. Analog vs. Digital Indications (I)

Now imagine that we deliver exactly the same very small quantity of product from both systems. The indicators then might appear as in Figure 3-13.



Analog Indicator Digital Indicator

Figure 3-13. Analog vs. Digital Indications (II)

It is clear from the reading of the mechanical indicator on the left that some additional 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 visually we can arrive at an approximate reading of 100.04 gal. The digital indication 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 (since, like most digital indicators, it is designed to round up to the next higher value half-way between two consecutive values, and will thus read 100.1 gal for all deliveries between 100.05 and 100.149 gal).

What difference does this make? To the buyer and seller of the product it will make virtually no difference at all. In our example, if the price of the product is $1.00/gal and if the operator of the analog device follows the practice of rounding up to the next higher volume quantity, the buyer from the digital system will have received a penny's worth of "free" product for a delivery costing $100.00 – an insignificant amount. But to a weights and measures inspector conducting an official test, 0.04 gallon could be very significant. As you will learn in Chapter 6, the tolerance specified in Handbook 44 for a 100-gallon test draft delivered from some vehicle-tank metering systems that are new or that have been recalibrated or reconditioned within the past 30 days is only 0.15 gal (34.65 cu in). In such a test situation, a meter could easily be erroneously rejected (or erroneously approved) on the basis of a difference of 0.04 gal!

In fact, most electronic registers are capable of being programmed to indicate hundredths of a gallon for test purposes, and some models are equipped with light-emitting diodes that light up at the midpoint of the smallest indicated increment. As a result, this will rarely present a practical problem for you in the field. However, it points out the reason for the general distinction between analog and digital registers. As you will see, this distinction is also significant in other ways.

Weights and measures regulations require that all vehicle-tank meters used in commercial transactions must be equipped with a means of resetting the register to zero prior to the start of a delivery. The reason for this requirement will be described in detail in Chapter 5. On a mechanical register, the reset control is usually a lever or knob on the side of the register, like the one shown in Figure 3-8. Operating the control all the way to its stop will turn the indicating wheels (usually forward) until all of them are in a definite zero position. The reset control on an electronic register is usually a pushbutton that, when depressed, clears the display, as in the example shown in Figure 3-14.

If the device is cleared by advancing its elements to zero, it is also required that some effective means be provided to prevent the device from displaying any readable indication during the course of the resetting process (see also Chapter 5). Most mechanical registers are equipped with shutters that cover the indicating wheels while they are being advanced to zero. On electronic meters the display is blanked out completely while the circuits are being cleared and reset.

In addition to the resettable "primary" indicating element, most registers also have cumulative indicators, more commonly referred to as totalizers (see again Figures 3-8 and 3-14). These displays are used by the owner or operator to monitor sales and inventory and to provide a means of detecting pilfering of product by employees. The totalizers can usually be reset by the owner or operator, but are protected by security seals or codes from unauthorized resetting. Since they are usually not used as the basis for commercial transactions, totalizers are generally not subject to weights and measures requirements regarding accuracy, readability, etc.

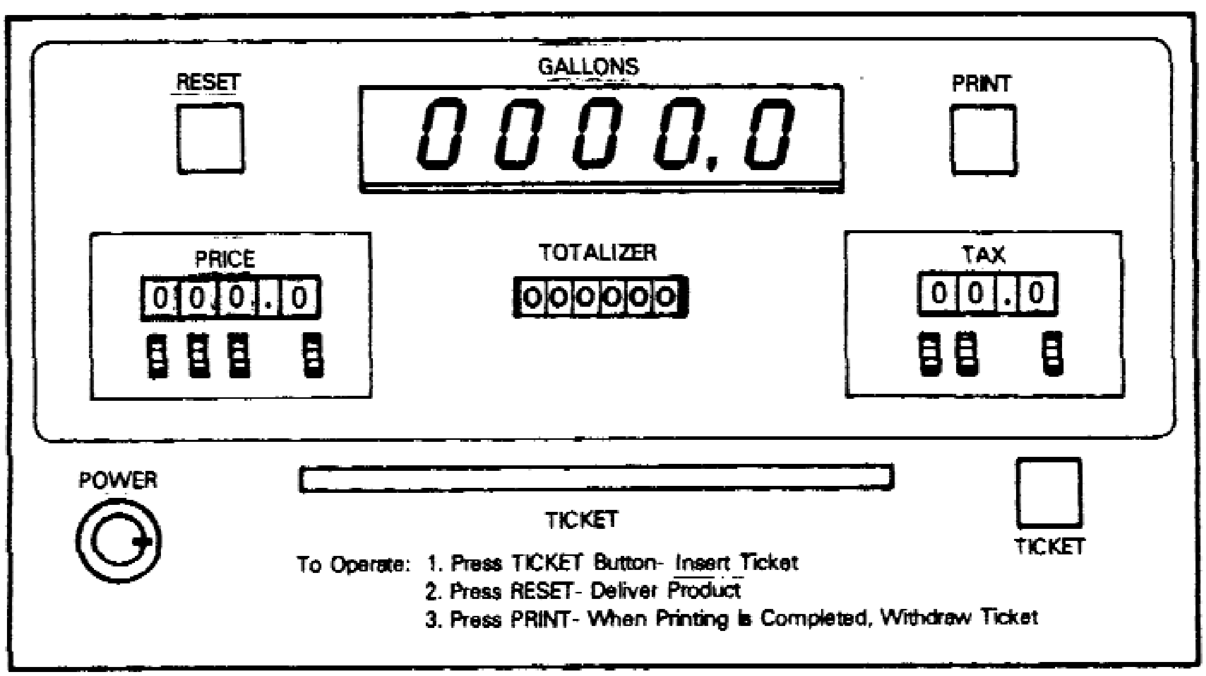


Figure 3-14. Electronic Register

However, the inspector will use them to determine the total amount of product dispensed during tests. The operator can then be informed of the extent of the discrepancy in his or her inventory to be attributed to testing (since product is returned to the truck tank at the conclusion of tests, but will have been registered on the totalizer as delivered).

The Calibrator

When a vehicle-tank meter is calibrated, 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 adjusted to bring the indication 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 designs, this is accomplished by actually changing the drive gears: the larger the driving gear in relation to the driven gear, the more revolutions the driven gear will make per revolution of the driving gear (its relative rate of revolution will increase), and vice versa. Such an adjustor is appropriately called a "gear changer." The adjustment mechanism itself is usually calibrated so that an adjustment of a single step will effect a predictable change in the indication per gallon metered. For example, a typical adjustor might be capable of stepped corrections in increments of 0.5 cubic inch per gallon metered.

As you might expect, calibration of electronic registers is performed electronically. The operator or repairperson determines a "calibration factor" based upon the error observed during a performance test. This factor is read into the system circuitry and subsequently corrects all indications by a consistent amount. Recalibration is based upon the current meter factor.

A meter can only be calibrated effectively when its errors are reasonably consistent over its full range of operating conditions. A meter that is excessively worn will register erratically, and its inaccuracy will eventually vary widely at different flow rates. The calibrator can thus be considered a fine tuning instrument for a meter that is not badly worn or damaged. At some point, however, the calibrator will no longer be capable of correcting the meter to within acceptable limits of inaccuracy (tolerances), and the meter itself will then have to be reconditioned or replaced. The topic of meter wear and recalibration will be discussed further in Chapter 6.

The Printer

Handbook 44 requires that, except for systems used solely for the sale of aviation fuel into aircraft and for aircraft-related purposes, vehicle-tank metering systems be equipped with a ticket printer, and the device owner must use the ticket printer for all sales where product is dispensed through the meter. (A contrasting example is one in which an entire truckload of product is gravity dropped at a service station rather than running the product through the meter on the back of the truck. In this case, the customer is provided with a printed invoice from the loading-rack meter system used to fill the vehicle-tank truck. Because product is not delivered through the meter for the sale, the ticket printer on the vehicle-tank meter is not required to be used for the delivery.) In addition to using the ticket printer for all sales, the seller must leave a copy of the ticket with the customer at the time that the delivery is made unless the customer makes other arrangements with the seller.

Ticket printers reduce the operator's effort and are consistently accurate, whereas hand-printed invoices take time to prepare and are sometimes inaccurate due to errors in reading of the register indications, errors in transcription, or in computations made by the operator.

A ticket printer is driven directly by the register, either mechanically or electronically. The recorded representations produced by a ticket printer are required to be digital. That is, the quantity delivered (as well as the total price and unit price if the system is of the computing type) must appear on the ticket as numbers. It would not be acceptable, for example, for the printer to show a representation of indicating wheels or a dial with graduations and an indicator, even if this is the means by which the register indicates amounts and values. This requirement applies regardless of whether the register produces analog or digital indications. Computing-type registers (described in detail in Chapter 5) may also provide complete invoice information for a compatible printer, including the unit price of the product, quantity delivered, and total sale price. A number of specific requirements apply to the design, installation, and use of ticket printers. These requirements will be explained in detail in Chapter 5.

Temperature Compensators

A temperature compensator is basically an automatic calibrator, and the design of its correcting elements is similar. A sensor located in the product line relays the temperature to these correction elements.

Devices designed and used to correct register indications for the effects of temperature on product volume may not be as common on vehicle-tank meters as other devices. However, specific requirements for Temperature Compensation were added to the Vehicle Tank Meter Code of Handbook 44 in 2007. Several States permit their installation, and they are available through a number of manufacturers. You should understand your jurisdiction's policies and procedures regarding field examinations of vehicle-tank meters that are equipped with temperature compensators.

The Discharge Line

After product passes through the meter it enters the discharge line. The elements of the discharge line include a main control valve, a discharge hose, and, on power-operated systems, a discharge nozzle. Power-operated systems are also equipped with automatic directional flow valves. A preset control device is optional.

The Control Valve

The control valve is the main flow control on both gravity-discharge and power-operated systems; although in the latter the discharge nozzle can also be used to regulate flow during delivery. The control valve is located at the outlet of the meter. The design and operation of the valve are straightforward, as you can see in Figure 3-15.

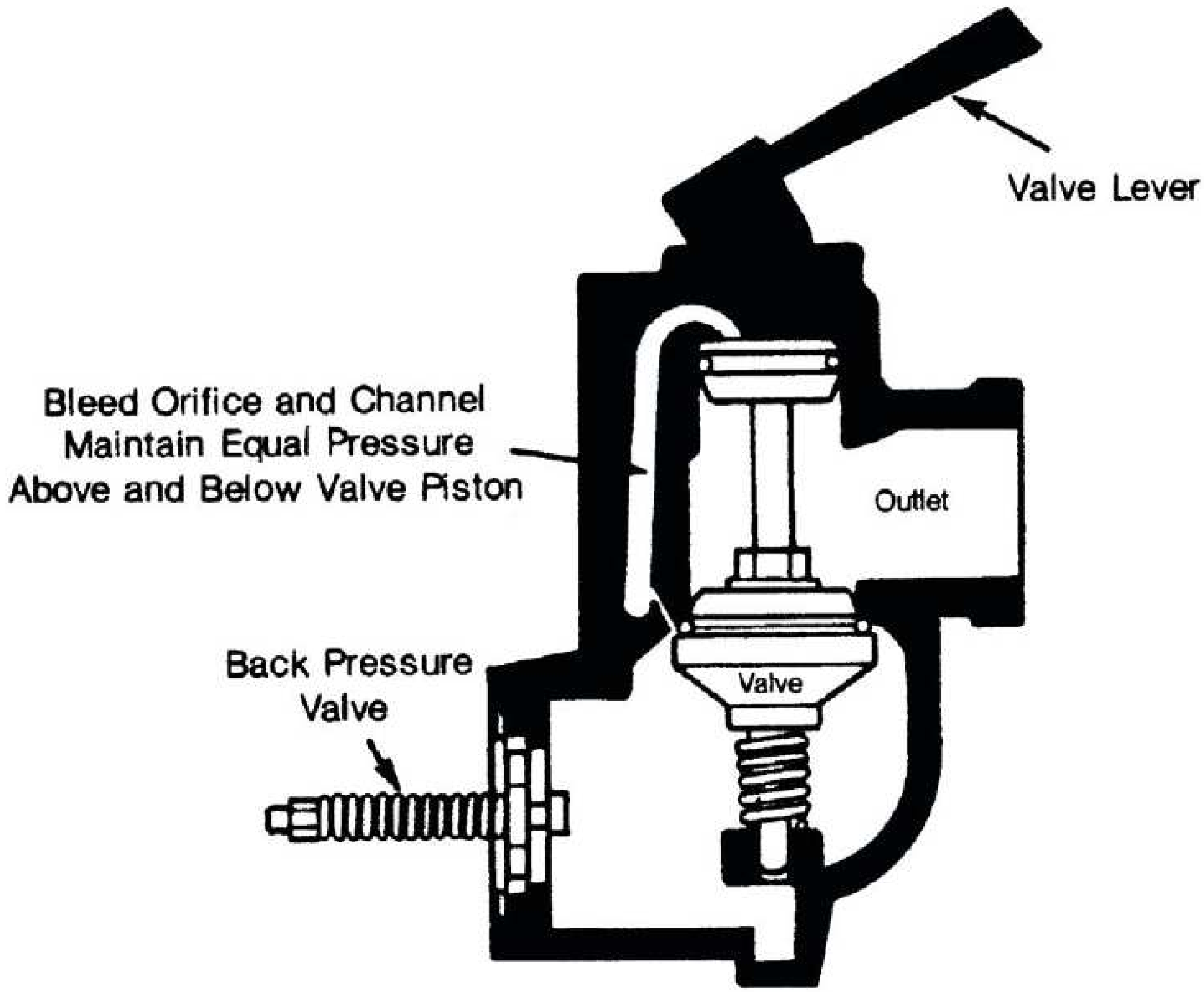


Figure 3-15. Cutaway Diagram of Control Valve

Most control valves, like the one depicted, have a design that maintains balanced pressure on both sides of the valve throughout its operation. This prevents the valve from opening or closing abruptly and, thus, minimizes hydraulic shock in the meter and discharge line. This particular design employs a bleed tube and orifice. Others incorporate a two-stage valve, similar to the air eliminator vent valve shown earlier.

You will notice that this control valve is equipped with a back-pressure valve at its inlet. A back-pressure valve requires a calibrated amount of pressure on the inlet side to keep it open. So pressure in the meter, in the air eliminator, and back through the supply line is maintained at or above the desired back pressure. This helps the air eliminator function more efficiently by preventing the product level from fluctuating with changes in discharge flow.

Notice also that this control valve functions as a check valve, allowing product to flow only in the direction of the outlet and discharge line. This prevents the system, and especially the meter, from draining backward toward the supply. Most manufacturers recommend that a back-pressure valve be used with power-operated systems. A back-pressure valve is not necessary in gravity-discharge systems, and might inhibit delivery at low head.

The Preset Control

Many vehicle-tank systems that make primarily partial-load deliveries, such as home heating oil trucks, are equipped with a preset control device, sometimes referred to as the quantrol (short for "quantity control"). The operator can set this device to deliver a predetermined quantity of product and then shut off delivery automatically. It is then unnecessary for the operator to monitor the delivery at the meter/register. He or she may instead stand at the discharge nozzle, which may be some distance away. The preset is linked, either mechanically or electronically, to the meter shaft and to the control valve. It is usually mounted on the meter "stack," that is, either on top of the meter or on top of the register. In some systems, the preset is incorporated in the register.

The operator punches in the desired quantity on the preset display, using a separate pushbutton to set each digit (see Figure 3-16). This establishes a trip point. When the delivery begins, the preset functions just like a register, but counts backwards, indicating continuously on its quantity wheels the amount left to be delivered. When the delivered quantity reaches the preset trip point and the preset indicates zero, the device actuates the control valve, shutting off flow.

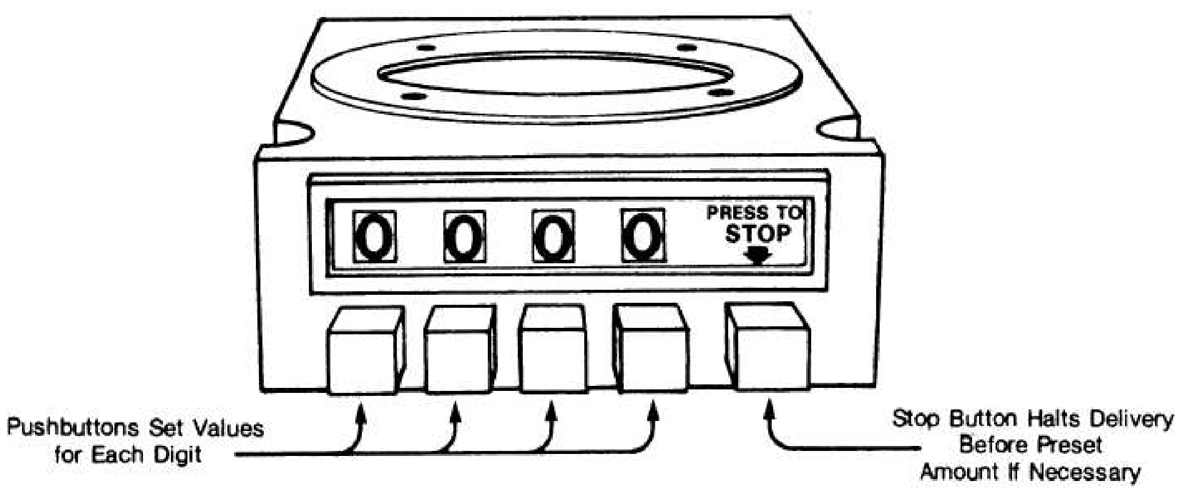


Figure 3-16. Preset Control

The Discharge Hose

As mentioned earlier, the discharge hose on a gravity system should be no longer than necessary to drop directly to the underground storage fill opening. The short hose facilitates complete drainage at the conclusion of the delivery. For the same reason, gravity-discharge hoses are reinforced so that they are semi-rigid. Since the system is of the dry-hose type, the discharge end of the hose is not equipped with a valve. The delivery is regulated entirely at the control valve.

The discharge hose on a power-operated system, on the other hand, may have to be much longer to reach its delivery point (as is often the case for home heating oil deliveries), and its length will not be limited by the necessity of draining it completely, since it is a wet-hose system. However, the hose should still be no longer than necessary. A shorter hose will reduce pressure drop and the effects of ambient temperatures on the system by reducing surface area. The use of a hose reel protects any unused length of discharge hose from exposure to the effects of wind and sun.

The discharge nozzle on a power-operated system has two essential functions:

- to regulate discharge at the delivery point
- to prevent drainage of the discharge hose

The first of these is performed by a manually operated valve, with a lever-type operator. This allows the driver to regulate the delivery at the fill station, which may be at some distance from the truck. At the conclusion of the delivery, the driver closes the discharge nozzle valve, then returns to the truck, closes the control valve at the meter, and disengages the pump from the truck engine to complete the system shutdown.

The discharge nozzle on a power-operated system must also be equipped with an antidrain valve. The antidrain valve is installed in the nozzle inlet and is similar in design to the back-pressure valve we looked at earlier. It is calibrated to open only under pressure. When the driver closes the control valve at the meter, pump pressure is no longer supplied to product in the discharge hose, and the anitdrain valve will no longer open, even if the discharge nozzle valve is open. Thus the antidrain valve, when functioning correctly, effectively prevents the discharge hose from being drained, thereby assuring accurate registration of the quantity delivered.

In some power-operated systems, the discharge nozzle is also equipped with an automatic shutoff valve, which functions in the same way as its counterpart on a gas pump, shutting off the flow when the tip of the nozzle comes in contact with liquid rising in the receiving tank fill pipe. This valve permits deliveries to be made to the capacity of the receiving tank, "topping it off," without danger of overfill or excessive back pressure on the nozzle valves.

Summary

A number of separate elements work together to assure the safe, efficient, and accurate operation of a vehicle-tank metering system. Because of their functional interdependence, the failure or malfunction of one element can inhibit the effectiveness of others and impair the correct operation of the entire system. Specific requirements relating to the selection, installation, maintenance, and use of these elements are described in detail in Chapters 5 and 6.