Chapter 2

The Vehicle-Tank Metering System

Chapter Objectives

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

1. Describe the vehicle-tank metering system, its uses, and its relation to other liquid-volume measurement and delivery systems.

2. Explain the difference between gravity- and power-operated vehicle-tank metering systems.

3. Describe the major functional components of the vehicle-tank metering system.

Introduction

Vehicle-Tank Meters and Their Relation to Other Liquid-Measuring Devices

As is obvious from their generic or common name, vehicle-tank meters are measuring devices that are employed in commercial deliveries of products from tank trucks. It may not be at all obvious, however, why NIST Handbook 44 distinguishes vehicle-tank meters as a class from several other types of devices that are quite similar in design and function. It would seem logical that their classification has something to do with the fact that they are mounted on tank trucks, but in fact this is not the primary reason.

To understand how and why vehicle-tank meters are distinguished, you must first be aware of their relation to these other classes of metering devices, each of which is treated as a distinct class in Handbook 44:

- retail motor-fuel dispensers ("gas pumps")
- loading-rack meters (used to measure deliveries from stationary storage facilities, pipelines, etc.)
- LPG meters (used for metering liquefied petroleum gases, such as propane and butane)
- cryogenic meters (used for metering liquid oxygen, nitrogen, and argon)
- milk meters
- water meters

All the devices listed above share three important features:

- They are used exclusively for measuring liquid products (or, in the case of LPG and cryogenic meters, products that are sold in a liquid state).

- They all mostly employ the positive displacement method of measuring liquid volume (described in detail in the next chapter of this module). (Only positive displacement meters are covered in this module.)

- They are designed to measure and deliver product simultaneously, as opposed to measuring devices like graduates or capacity containers in which the liquid is measured first and then delivered. (Another example of the latter type of device is the old fashioned gas pump, which was operated by first pumping gasoline into a graduated cylinder until the desired amount was indicated, then draining the cylinder into the motorist's fuel tank.)

These are basic similarities among these different classes of liquid-measuring devices, but there are many more particular likenesses in design and function. For example, gas pumps, loading-rack meters, and vehicle-tank meters are used for dispensing gasoline and other motor fuels, and both LPG and cryogenic product meters are commonly mounted on tank trucks (although they are not classified as "vehicle-tank meters" in Handbook 44 codes). Many of these meters are manufactured by the same companies, and some are so similar in design and appearance (especially certain models of vehicle-tank and loading-rack meters) that they are virtually indistinguishable as they come from the factory. Given their many similarities, why are these classes of metering devices differentiated for weights and measures purposes? Is the classification simply arbitrary?

Of course, the answer is that the classification is not arbitrary. Although many of the requirements set forth in Handbook 44 for these separate classes are identical, there are significant differences. These differences reflect, for the most part, the different ways in which these very similar devices are used in the commercial marketplace. These usage factors generally affect the design of the device in ways that, in turn, affect the way it is examined in the field.

It is beyond the scope of this introduction to make a comprehensive comparison of these factors. Many of them will be apparent to you when you have had a chance to see the devices in operation in the field. But, it is important at this point in your training that you be aware, in general, of the reasons for the separate classification of these devices. So, let us consider a comparative example that relates directly to vehicle-tank meters.

Most gas pumps are designed for deliveries to highway vehicles and especially automobiles. The gas tanks on some compact cars hold no more than 10 gallons of fuel when full, and the standard fill pipe opening is less than 2 inches in diameter. Given these small dimensions, gasoline (or diesel fuel, gasohol, etc.) cannot safely be delivered to automobile fuel tanks at a rate of more than about 20 gallons per minute (gpm). In fact, most gas pumps that are used primarily for passenger cars have maximum discharge rates of between 12 and 15 gpm. In addition, to avoid overfill and to permit the operator to effectively control the delivery to within 0.01 gal, the dispenser must be capable of delivering fuel – and measuring it accurately – at much lower flow rates.

The fuel products dispensed at most filling stations are stored in underground storage tanks. These tanks vary in capacity with the needs of the operation, but may hold several thousand gallons of a particular product. Very large storage tanks hold as much as 12,000 gallons. These storage tanks are supplied periodically by tank trucks, which may deliver as much as several thousand gallons of product to a large tank (for obvious reasons, deliveries are made before the storage tank is nearly empty). Consider a delivery of 5,000 gallons of gasoline. If a meter like the one installed in the station's dispenser was used, the delivery would take more than 5½ hours! Obviously, the vehicle-tank meter installed on the tank truck will be designed to operate at a considerably higher delivery rate in order to reduce the overhead costs associated with a single delivery. Meters installed on petroleum tankers typically operate at maximum flow rates ranging from 40 to 180 gpm.

The tank truck, in turn, picks up its load from a distribution facility which uses a loading-rack meter to measure the amount of product dispensed to the truck. Because the truck tank may have a capacity of as much as 9,000 gallons or more, the same economic factors will dictate that the loading-rack meter operate at a proportionately higher flow rate than the vehicle-tank meter installed on the truck. Some loading-rack meters are capable of discharge rates as high as 1,000, or even 1,500 gpm, 100 times the flow rate of the gas pump that is used to make the final delivery of the product to the consumer. Note that most of these tankers today are not equipped with meters. Instead, they drop the entire tanker load into the storage tank of the buyer and rely on the quantity determination made by the meter at the loading rack as the basis for the sale.

All three meters involved in the delivery of this product are capable of comparable accuracy, and are required to deliver the indicated volume of product to a tolerance that depends on the accuracy class of the meter. But to test the accuracy of these three metering devices requires different equipment and, to some extent, different procedures. We have pointed out that these meters are designed to operate at widely different delivery rates because this is perhaps the most significant factor in determining how they will be tested. For reasons that will be explained in greater detail in a later chapter, a performance test for any liquid-measuring device operating at a delivery rate equal to or greater than 20 gpm requires a test draft the volume of which is at least as great as the quantity that the device can deliver in one minute at its maximum flow rate. For any liquid-measuring device operating at a delivery rate of less than 20 gpm, a test draft of at least 19 liters or 5 gallons is required. So for the typical meters described above, the inspector might have to draw quantities of 5, 180, and 1,500 gallons, respectively, necessitating the use of three different sized provers.

The point of this extended example is that the differentiation of liquid-measuring devices into a number of classes is based upon differences in typical operating characteristics, such as maximum flow rate, that may affect the way the device is tested in the field. Thus, vehicle-tank meters form a distinct class not because they are mounted on tank trucks, but because their operating characteristics typically fall within a range that is distinguishable from other types of meters.

The Vehicle-Tank Metering System

As a weights and measures inspector, you are primarily concerned with the ability of a vehicle-tank meter to measure and indicate the quantity of product delivered accurately. However, because these devices are designed to measure and deliver product simultaneously, their ability to do this depends upon the proper functioning of the entire dispensing system, of which the measuring and indicating elements are only a single component. So it is important that you understand this system.

All vehicle-tank metering systems consist of four essential components (illustrated in Figure 2-1): the tank, the air eliminator, the measuring and indicating elements, and the pipelines and control elements that regulate the passage of the product from the tank, through the meter, and to the point of delivery. Let us now look briefly at the function of each of these components. A detailed discussion of their operation will be presented in the next chapter.

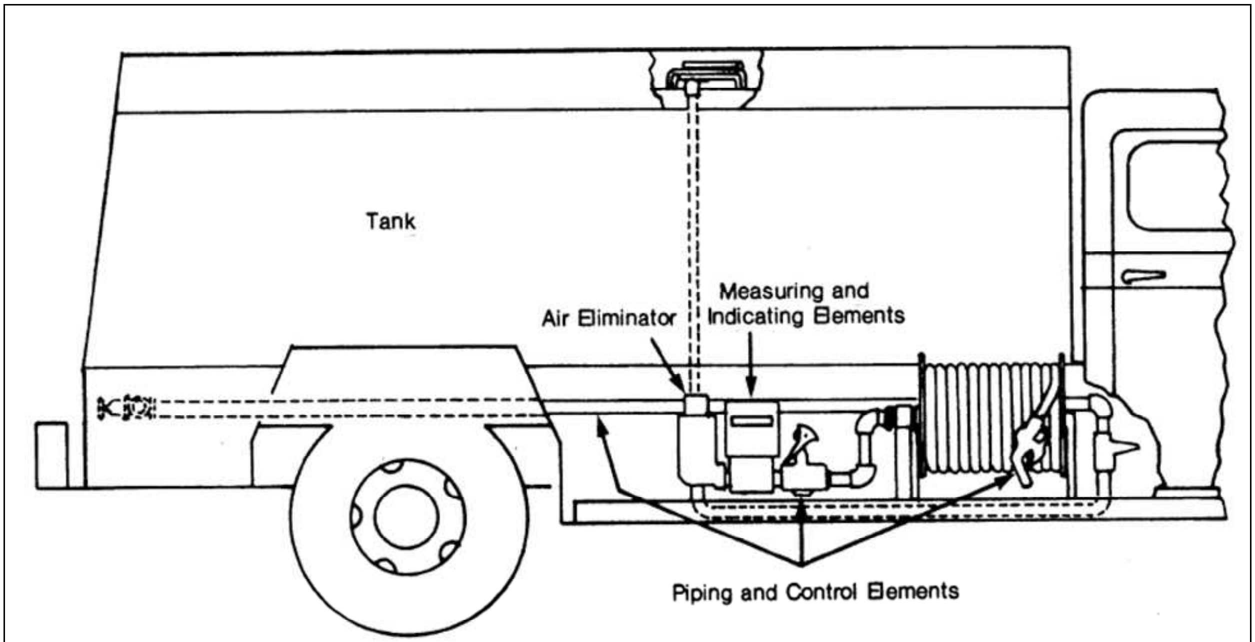

Figure 2-1. The Vehicle-Tank Metering System

Truck-mounted tanks range in capacity from several hundred to several thousand gallons. The tank trucks that are used to deliver home heating oil typically hold about 2 500 gallons of product; petroleum "super-tankers" may hold more than 9 000 gallons (a maximum capacity is often established by State law). The tanks are equipped with baffles, partial partitions that prevent excessive shifting of the fuel when the truck is in motion and accelerating or decelerating. The tank may also be divided into separate compartments. This permits the truck to be loaded with different products (for example, different grades of gasoline). The tank, or separate tank compartment, is usually filled from the top. The fill opening is securely covered at other times to prevent spillage, contamination of the product, and air pollution due to excessive venting of vapor. The tanks are also equipped with relief valves, usually installed in the fill opening cover(s), which allow air to be drawn into the tank to relieve the partial vacuum created as the liquid level drops during delivery, and to permit air and vapor to be vented when thermal expansion of the product causes pressure inside the tank to exceed a safe amount.

During delivery, product drains through an outlet in the bottom of the tank, and is carried through piping toward the meter. If the tank is divided into compartments, the product usually passes first into a manifold (see Figure 2-2), which has one inlet connected to each tank compartment, and a single outlet connecting it to the intake line heading toward the meter. The manifold inlets are equipped with valves, so that the product is drained from only one compartment at a time.

Small amounts of air and product vapor are often mixed with the liquid contents of the tank. These entrapped gases must be removed from the liquid before it is metered, so that they are not measured along with the product that the customer is paying for. This is typically accomplished by the air eliminator, which separates the entrapped or entrained gases from the liquid flow and vents them, either back into the storage tank (See Figure 2-3) or, in the case of one type of system, to the receiving tank via a bypass around the meter to the discharge line (See Figure 2-2).

The liquid product, now free of air and vapor, passes through the meter, and the mechanical action of the meter caused by its passage produces a continuous indication of the quantity that has been delivered. The indicating device is usually called the register. These are the measuring and indicating elements.

The metered product then passes through the discharge line to a nozzle, which is connected to the fill opening of the receiving tank. The flow of product is controlled by valves that are located on the discharge side of the meter, either at the meter outlet or at the discharge nozzle. These, along with the manifold and intake lines, are piping and control elements.

These four functional components – tank, air eliminator, measuring and indicating elements, and piping and control elements – are employed in all vehicle-tank metering systems. Before we consider them in more detail, however, you should be aware of the two basic types of systems that are in use.

Gravity-Discharge and Power-Operated Systems

Some tank trucks are used exclusively for making deliveries to underground storage tanks (for example, tankers that supply motor fuel to gas stations). This type of system is diagrammed in Figure 2-2. Since the product is delivered to a tank that is entirely below the level of the truck tank, it is most efficient to allow the pressure that result from the level of the product in the tank (the "head") to propel it through the system. This type of system is known as a gravity-discharge system. The delivery rate of a gravity-discharge system will depend upon the quantity of product in the truck tank, since it is the head pressure that propels the liquid. A typical gravity-discharge petroleum tank truck is capable of delivering at rates between about 90 gpm at "low head" (that is, as the quantity of product in the tank approaches zero) to approximately twice the rate – about 180 gpm – at "full head" (when the truck tank is full). A typical average delivery rate is more than 125 gpm.

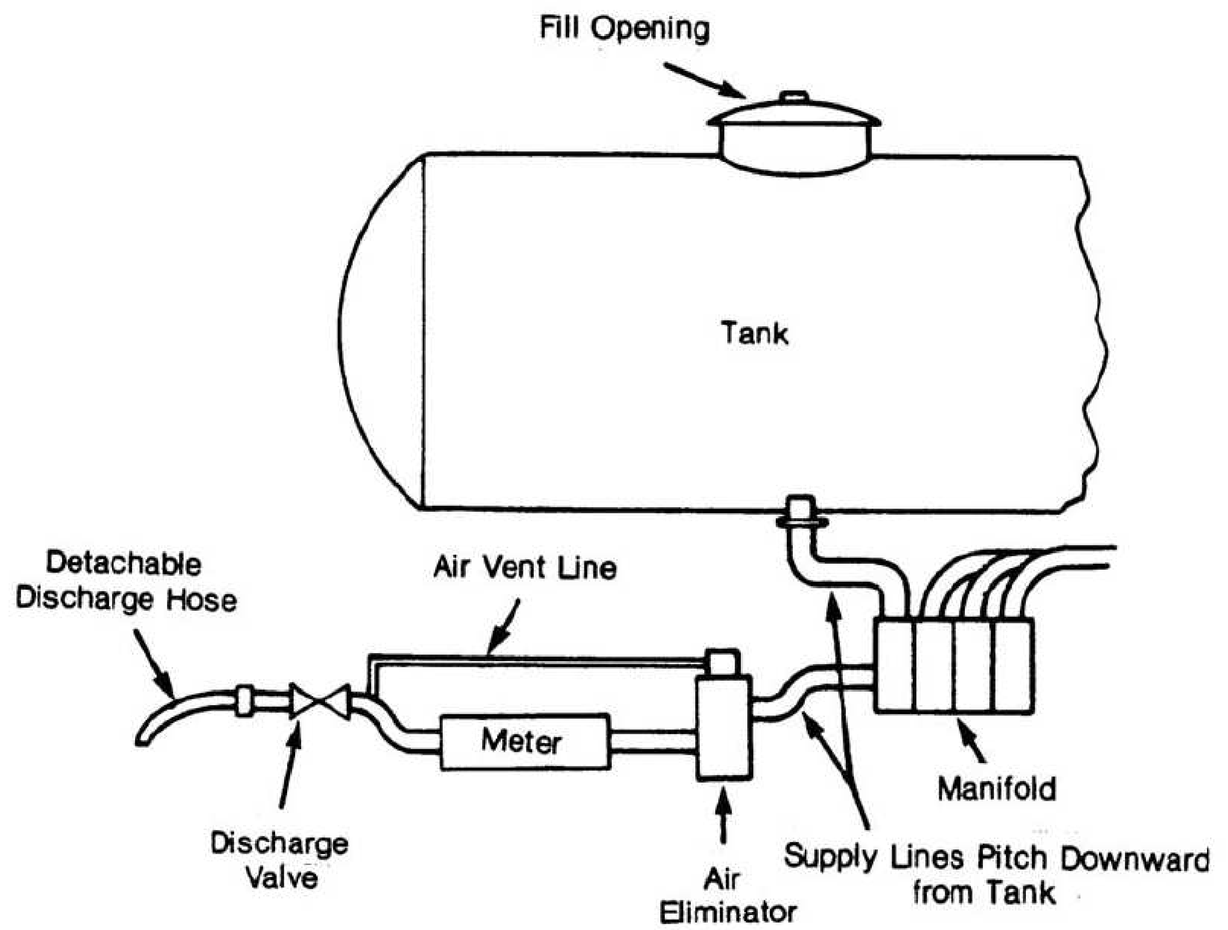

Figure 2-2. Diagram of a Gravity-Discharge System

When the product must be delivered to a storage tank that is above ground, a pump (usually driven by the vehicle engine) is used to provide the pressure required to deliver the product. This type of system, called a power-operated system, is diagrammed in Figure 2-3. The most common example of a power-operated vehicle-tank metering system is the truck used for deliveries of home heating oil. Maximum discharge rates for power-operated systems are generally slightly lower than those for gravity-discharge systems, ranging from 30 gpm to 100 gpm (although some power-operated systems are capable of delivery rates of 300 gpm or more).

Aside from the presence or absence of a pump, gravity- and power-operated systems are, in most respects, identical in design and function. In fact, most meters can be used for either type of system, and some trucks can make either gravity- or power-operated deliveries as needed, simply by using a bypass around the pump for gravity-discharge deliveries. There are several minor differences, which we will discuss in greater detail in later chapters. However, there is one major difference that you should understand from the start.

At the end of a delivery, the discharge line from the meter outlet to the nozzle will be filled with liquid that has passed through the meter, and thus has been charged to the purchaser. Some means must be provided to assure that this quantity of product is actually received. In a gravity-discharge system this is accomplished by draining the discharge line completely into the receiving tank. The line is attached near the meter outlet by means of a detachable connector (see Figure 2-2) so that it can be removed and raised to a vertical position to allow complete drainage of the hose. To accomplish this, the length of the discharge line must be kept to a minimum; ideally it will be no longer than needed to drop straight from the meter to the receiving tank fill opening.

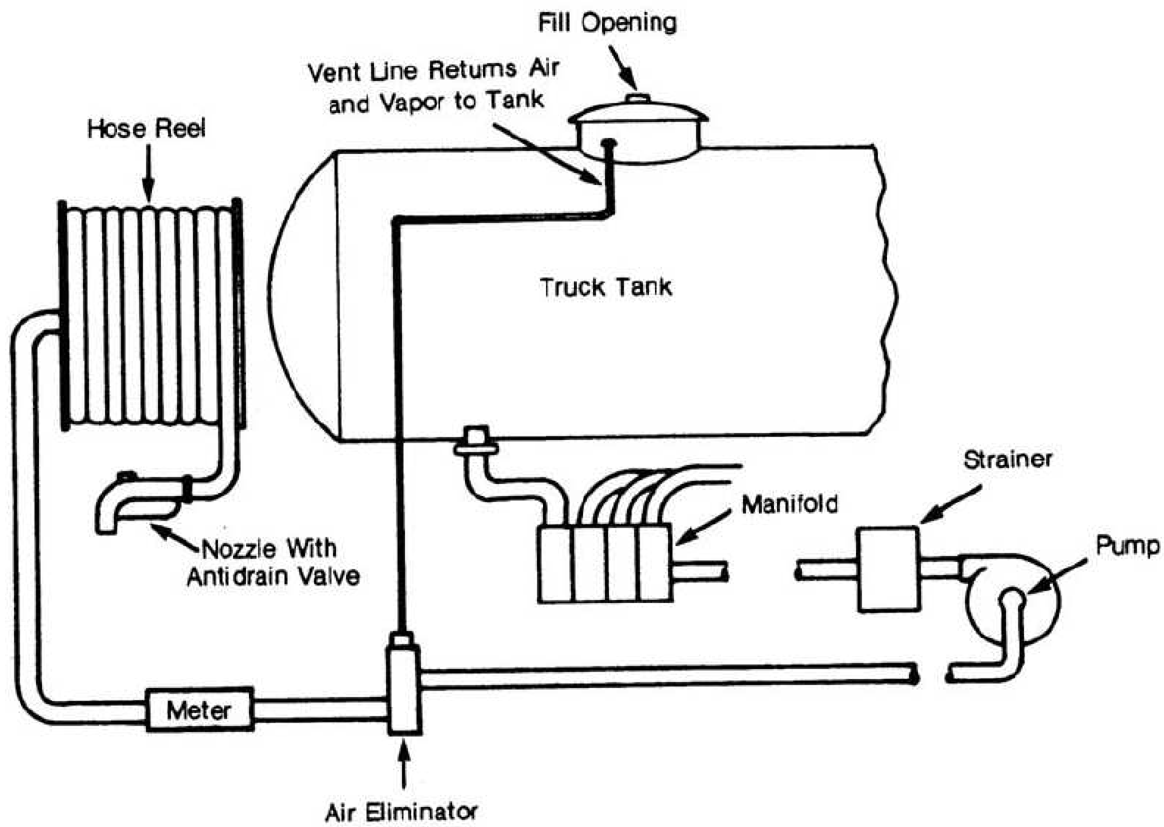

Figure 2-3. Power-Operated System

In a power-operated system the length of the discharge hose and the relative height of the delivery point make draining the hose impracticable. So the entire discharge line, from the meter to the inlet of the discharge nozzle, is kept full of product at all times. An antidrain valve installed in the nozzle prevents product from being discharged when pump pressure is no longer being supplied. Since the discharge hose contains the same quantity of product at the beginning and end of each delivery, the entire amount of product indicated will actually have been delivered to the receiving tank.

A gravity-discharge system is referred to as a "dry-hose" system, because the discharge hose is emptied of liquid at the end of each delivery; a power-operated system is a "wet-hose" system because the hose is kept full of liquid product at all times.

Summary

Vehicle-tank meters as designated in NIST Handbook 44 are used to measure products that are liquids at atmospheric temperatures and pressures as they are dispensed from tank trucks. As a class, vehicle-tank meters are distinguished from other liquid-measuring devices that are similar in design and function by their typical operating characteristics (maximum flow rates, etc.), not by the fact that they are mounted on tank trucks. The vehicle-tank metering system is comprised of four functional components: the tank, an air elimination device, the measuring and indicating elements (meter and register), and the piping and control mechanisms that connect these components and regulate their operation. There are two basic types of systems: (1) gravity-discharge systems, which are "dry-hose" systems; and (2) power-operated systems, which operate with a "wet-hose." Some systems are capable of operation in either mode.