CHAPTER 2

RETAIL MOTOR-FUEL SYSTEMS

CHAPTER OBJECTIVES

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

1. Define the following terms:
   - motor fuel
   - motor-fuel device
   - retail device
2. Identify the functional components or standard features of retail fuel-dispensing systems.
3. Differentiate between self-contained pump and remote dispenser types of fuel-dispensing systems.
4. Describe the difference between single-product and blended-product motor-fuel dispensers.
5. Recognize the features of electronic fuel-dispensing systems.

Retail Motor-Fuel Devices

This course deals with <u>retail motor-fuel devices</u>, one of several different classes of liquid-measuring devices for which specifications and tolerances are established in NIST Handbook 44 (Section 3.30.).

Retail motor-fuel devices are familiar to everyone by their everyday name—"gas pumps"—and for convenience, we can use this comfortable, if unglamourous, name without fear of being inaccurate. But all liquid-measuring devices are <u>not</u> gas pumps. For example, other liquid-measuring devices covered by this code include: wholesale meters (loading-rack meters), slow-flow meters, and lubricant devices. Different inspection and test procedures apply to each type of device. So, to avoid confusion, let's begin with some definitions, taken from Handbook 44 (Appendix D).

motor fuel. Liquid used as fuel for internal-combustion engines.

When we think of internal-combustion engines, the automotive engine—which powers cars, trucks, buses, and so on—probably comes first to mind. But internal-combustion engines also drive other types of vehicles, like boats, airplanes, helicopters, and some trains. And they are used as the power source for a great variety of machinery, like lawn mowers, chain saws, generators, farm equipment, compressors, and so on.

The most commonly used fuel for internal combustion engines is gasoline. But other liquid fuels, including diesel fuel, gasohol, and kerosene, come under our definition.

The term "motor-fuel device" is also defined in Handbook 44. A motor-fuel device must be designed both to measure <u>and</u> to deliver motor fuels. So a flow meter installed in a gasoline pipeline is not a motor-fuel device, since it does not deliver the product.

> **motor-fuel device or motor-fuel dispenser or retail motor-fuel device.** A device designed for the measurement and delivery of liquids used as fuel for internal-combustion engines. The term "motor-fuel dispenser" means the same as "motor-fuel device"; the term "retail motor-fuel device" applies to a unique category of device (see definition of "retail device").

The terms "motor-fuel device" and "motor-fuel dispenser" are used interchangeably in the Liquid-Measuring Devices Code (LMD). However, an important distinction is made between retail and wholesale devices. This distinction must be clearly understood, since many requirements in the LMD Code differ in substance or application depending upon which class the device being examined belongs to.

> **retail device.** A device for:
>
> single deliveries of less than 378 L (100 gal),
>
> retail deliveries of motor fuels to individual highway vehicles, or
>
> single deliveries of liquefied petroleum gas for domestic use and liquefied petroleum gas or liquid anhydrous ammonia for nonresale use.

In general, <u>retail</u> devices are distinguished from <u>wholesale</u> devices, which may be of similar design, but are used to deliver product—usually in large quantities—that is intended for resale. So, for example, a motor-fuel device that is used to measure gasoline as it is being loaded into a tanker truck for delivery to a gas station would be considered a wholesale, not a retail, device, since the gasoline will be sold again. Separate specifications and tolerances for wholesale devices recognize differences in design characteristics and operating conditions associated with delivering large quantities of motor-fuel products.

Our definition includes all motor-fuel devices that are used for retail deliveries to <u>highway vehicles</u>, from motorcycles to the largest trucks, which may be equipped with multiple fuel tanks. But it also includes any motor-fuel device that is designed for deliveries of less than 100 gallons. So a gas pump installed at a marina to service boats, or at an airport to service private planes, is considered a retail device if it is designed for deliveries of less than 100 gallons. Again, these classifications are based on design characteristics and typical operating conditions, not exclusively on the type of business (wholesale/retail) in which the device is used.

The Fuel-Dispensing System

The design of the fuel-dispensing system for a gas station depends on a number of factors, including the size of the facility, its volume of business, the number of different grades, blends, or separate motor-fuel products sold, the desirability of such features as self service, remote cashiers, prepayment, multi-tier pricing—offering the same product at more than one price per gallon, depending upon the delivery and/or payment method (cash/credit, etc.)—and so on. So some systems are quite complex, others relatively simple. But all retail fuel-dispensing systems have three basic components: storage tanks, pipelines, and dispensers, as illustrated in Figure 2-1.

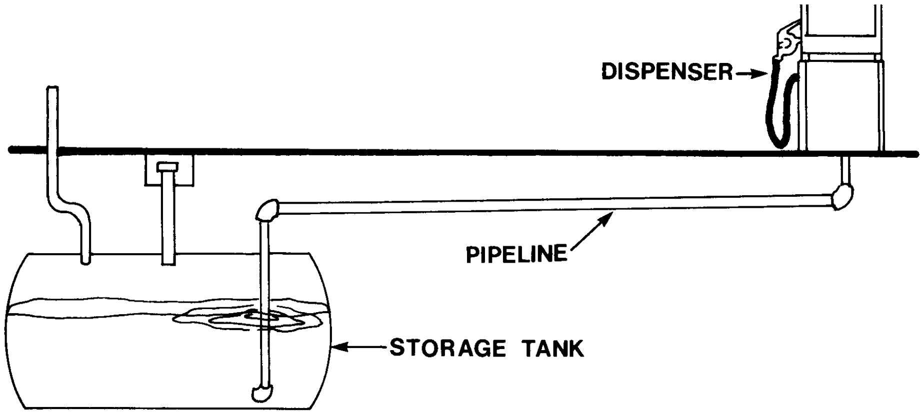


FIGURE 2-1. BASIC COMPONENTS OF THE FUEL-DISPENSING SYSTEM

At the present time, most storage tanks at retail motor-fuel facilities are installed underground, like the one shown in Figure 2-2. This location protects them from extreme temperature variations and from the dangers of accidental collision or fire, and permits aboveground space, which may be very valuable, especially in urban areas, to be used most efficiently. However, changes in Federal environmental protection regulations may encourage some facilities to install aboveground storage tanks in the future, since maintenance, including detection, containment, and cleanup of leaks is much easier when tanks are located aboveground.

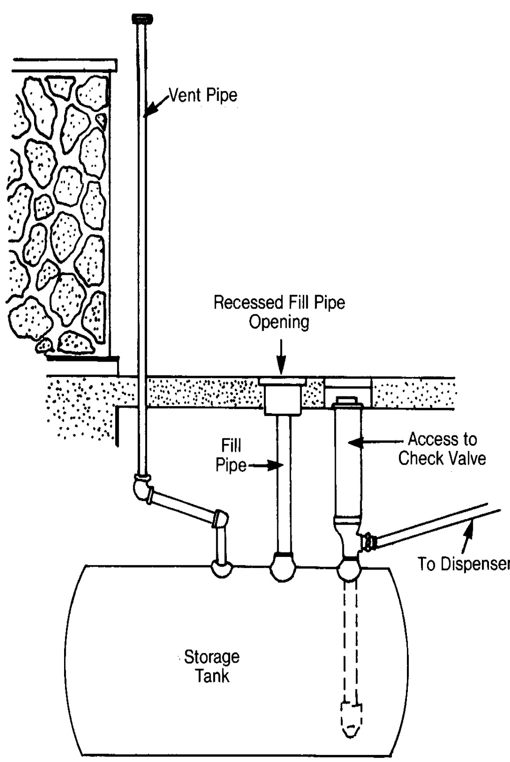


FIGURE 2-2. THE STORAGE TANK

Whether installed above or below ground, there is usually a separate storage tank for each grade or type of fuel sold at the station, except at stations that employ special equipment to produce blended products (described below). The size of a storage tank depends on the space available and the retailer's needs. Large storage tanks hold as much as 12,000 gallons of fuel (slightly more than 1,600 cubic feet).

When the tank is filled, the rising liquid level acts like a piston, pressurizing air and vapor in the upper portion of the tank. Conversely, as product is drained during delivery, the falling liquid level reduces the pressure. Without venting excessive pressure buildup could strain the tank and possibly cause leaks, and a pressure deficiency could strain the pumping mechanism and even make delivery through the system impossible, or encourage vaporization in the delivery lines. To prevent these conditions, storage tanks have vent pipes, which allow pressure within the tank to be maintained at a desired level (usually slightly above atmospheric pressure). The vent line is generally equipped with a relief valve, which opens at the preset pressure to permit air and vapor to be expelled from the tank into the atmosphere or air to be drawn into the tank from the atmosphere, as necessary.

In many States (or geographical areas), environmental protection regulations also require motor-fuel dispensing equipment to be equipped with vapor recovery systems, which prevent venting of vapor to the atmosphere during normal operation by balancing pressures between the discharging and receiving tanks. We will look more closely at vapor-recovery devices in the next chapter.

Storage tanks are filled periodically, usually from tanker trucks. In the case of underground tanks, a fill pipe (see Figure 2-2) extends from the tank to a level just below the pavement surface, where it is easily accessible, but safe from accidental impact from vehicles moving through the station. Fill pipes must be clearly labeled and/or color-coded to assure that the correct grade of fuel or fuel product is delivered. And they must be securely capped, to prevent contamination by dirt and moisture. In many States, over-fill containment is also required for below-grade fill pipes. Checking the labeling and security of fill pipes is one of the tasks specified in your inspection procedures.

Fuel travels from the storage tank to the dispenser through underground <u>pipelines,</u> which rise to the surface directly beneath the dispensers to avoid any risk of impact by a vehicle approaching or leaving the service island. Since a single storage tank can serve several dispensers, this piping may be quite extensive. It must be designed and installed with care to minimize the danger of fuel leaks.

Pipelines must also be buried far enough below the surface—usually at least 18 inches—to avoid a significant temperature differential between them and the storage tank. Liquid fuel tends to vaporize when heated. This is especially likely to occur in a particular type of dispenser, called a self-contained pump (described further below), in which fuel in the pipeline is under negative (suction) pressure. Under these conditions, fuel traveling from a relatively cold storage tank through warmer pipelines can vaporize, resulting in a condition called “vapor lock.” This condition sometimes occurs in automobile fuel lines, especially in very hot weather, for the same reason. If you have ever experienced vapor lock in your car, you know the result—fuel does not reach its intended destination. This disappointing result can also occur in fuel-dispensing systems that have not been properly installed.

The <u>dispenser</u> is the heart and brain of the fuel delivery system. It is also the component you will be primarily concerned with when conducting field examinations. As it delivers fuel to a vehicle through a specially designed hose and nozzle assembly, the dispenser simultaneously measures the volume and computes the price of the product delivered. The dispenser also contains a variety of control mechanisms, which regulate the rate of delivery, prevent over-fill and siphoning, and assure that the components that register volume and price are reset to zero at the beginning of each delivery.

The dispenser is a precision instrument, designed to register accurately within very close tolerances. You will see how this is done when we take a closer look at the dispenser and its operating components in the next chapter. But first you need to know the characteristics of several different types of fuel dispensers that are in common use.

Self-contained Pumps and Remote Dispensers

When fuel is stored in tanks below the dispensers, it must be brought to the surface against the force of gravity. This is done in one of two ways. The liquid fuel can be "pulled" toward the dispenser by a suction pump located in the dispenser unit, as in Figure 2-3 (actually, the product is propelled toward the dispenser by atmospheric pressure above the liquid surface in the storage tank).

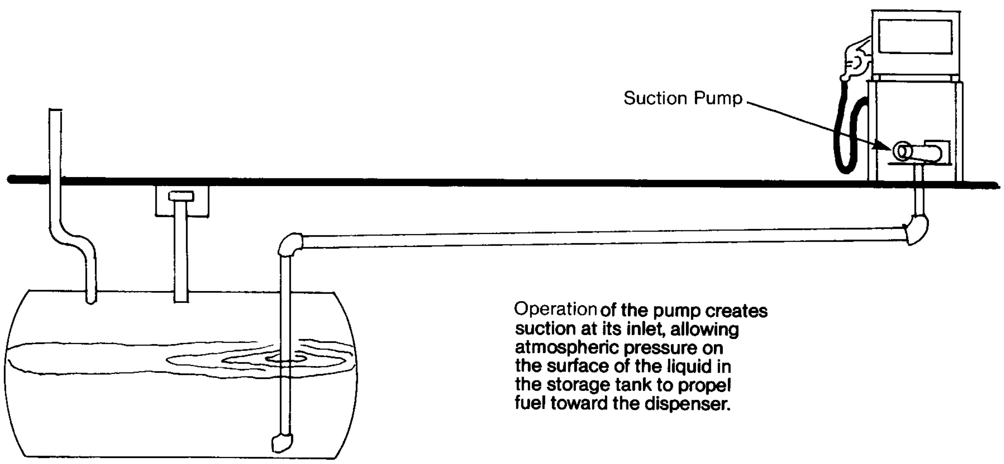


FIGURE 2-3. SELF-CONTAINED PUMP SYSTEM

A dispenser that contains a pump for drawing product from the storage tank is generally called a self-contained pump. A system in which fuel is pushed from the storage unit is usually called a remote-pump system, and the dispensers are commonly referred to as remote dispensers or dispensers. While, both types of dispensing systems are in common use, the majority of newer installations are equipped with remote dispensers. Both types have certain advantages and disadvantages.

When several dispensers are served by one storage tank, a single remote pump can supply product to the entire system, as illustrated by the system diagramed on the left in Figure 2-5. In a self-contained pump system, on the other hand, like the system diagramed on the right, each dispenser has its own pump, regardless of how many dispensers are served by the same storage tank. Alternatively, product can be pushed toward the dispenser by a pump located in the storage tank, as in Figure 2-4.

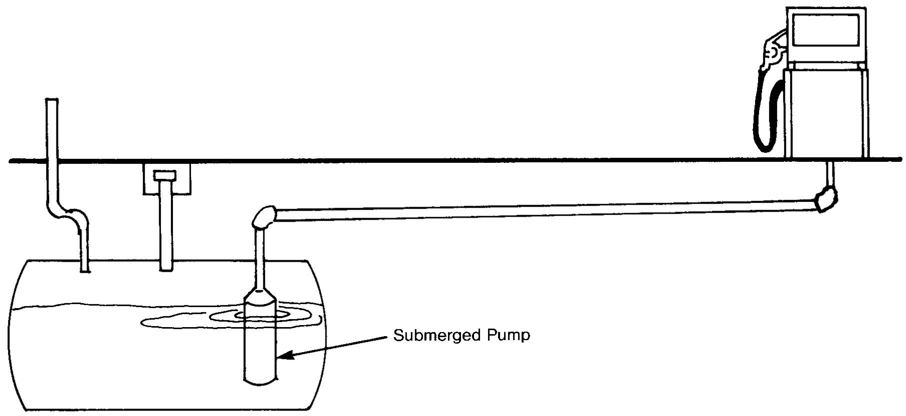
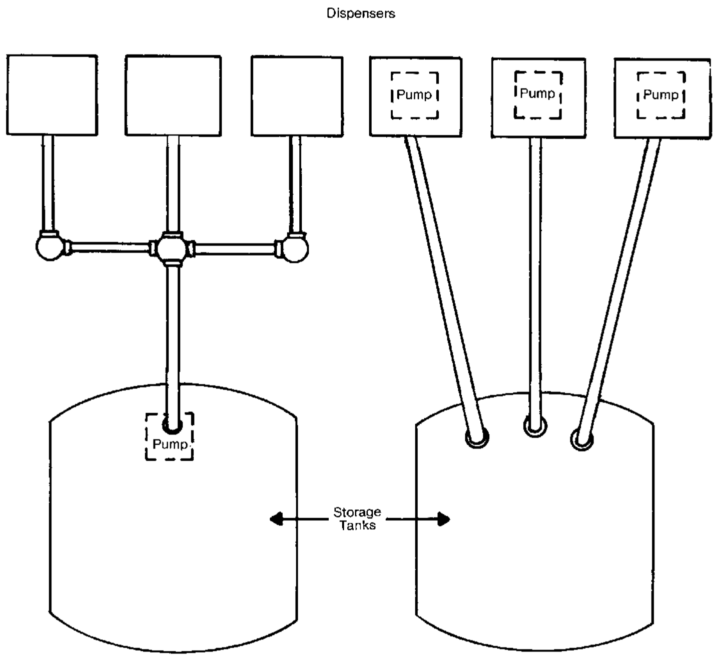


FIGURE 2-4. REMOTE DISPENSER SYSTEM

Over the life of the system, a single pump will obviously require less maintenance than several separate ones. So in a multi-dispenser system like the one illustrated in Figure 2-5, the remote pump seems to have a clear advantage. However, consider what will happen if that single remote-pump breaks down: the entire system will have to be taken out of service while repairs are being made. In a suction pump system, on the other hand, each dispenser operates independently, so if a pump malfunctions in one dispenser, the others can remain in service while repairs are made.

Deciding which type of system to install involves weighing the initial cost against long-term efficiency. But since each type has certain advantages in particular situations, you will find both used in the field.



Remote Pump Dispenser System — Self-Contained or Suction Pump System

FIGURE 2-5. MULTI-DISPENSER SYSTEMS

Dual-product Dispensers

Most service stations sell several different motor fuels: unleaded gasoline, often diesel fuel, sometimes gasohol, and even kerosene. In addition, gasoline is usually available in different grades: regular and premium, and often in intermediate grades. Each different product or grade can be held in a separate storage tank, and carried to dispensers through a separate pipeline.

Often, two complete dispenser assemblies are housed in a single chassis. These are called dual dispensers (they are also known as twins or duos). If each dispenser delivers the same product or grade, the unit is generally referred to as a single-product dual dispenser (or just 1-dual, twin, or duo for short). If the dispensers deliver different products or grades, the unit may be called a two-product dual dispenser (or 2-dual, twin, or duo).

Two-product dual dispensers (like the one on the right in Figure 2-6) are not, strictly speaking, variations on the basic configuration described above, since each dispenser is independent, having its own components and pipeline connection. But in a self-contained pump system, one-product dual dispensers (like the one on the left) may share a single pump, and, therefore, a single pipeline connection, as illustrated in Figure 2-7. This design reduces the number of suction pumps needed for a multi-dispenser system, but each dispenser must be equipped with its own control valve so that it can be operated independently. Figure 2-8 shows typical mechanical and electronic dual dispensers that you will encounter in the work place.

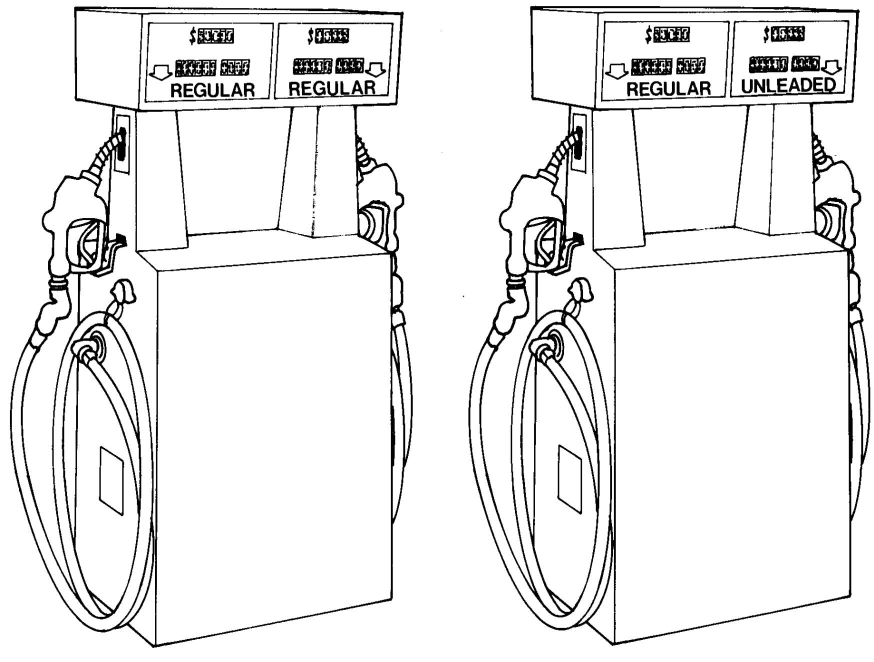


FIGURE 2-6. 1- AND 2-PRODUCT DUAL DISPENSERS

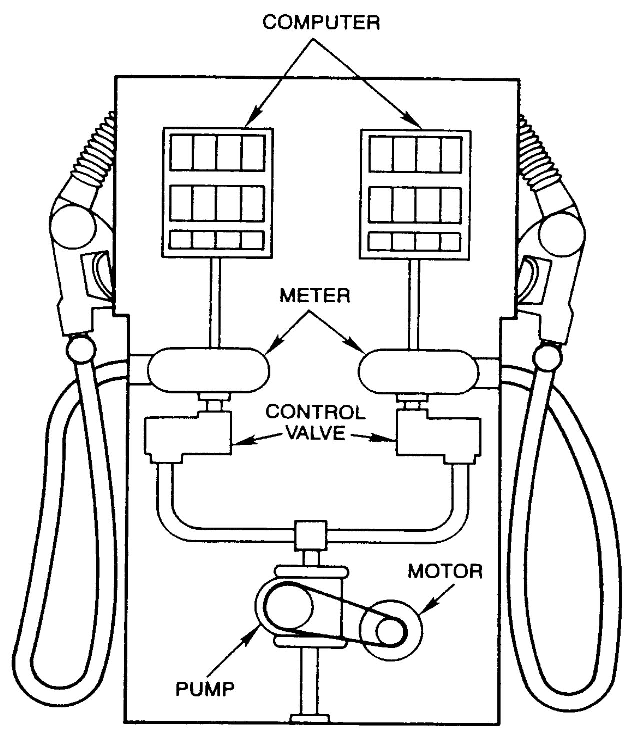


FIGURE 2-7. SINGLE-PRODUCT DUAL DISPENSER

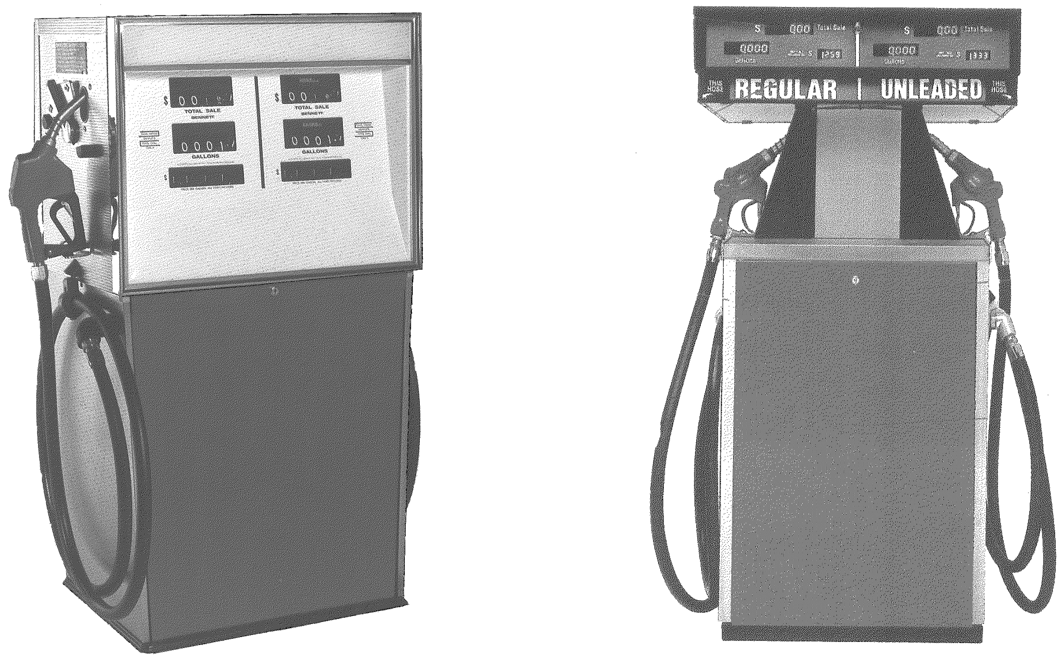


FIGURE 2-8. TYPICAL DUAL PRODUCT DISPENSERS

Multiple-product dispensers

For the past several years the most popular type of dispenser, especially in larger fueling outlets, has been the multiple-product dispenser. Here several grades of fuel may be selected from two, three, or even four hoses on the same dispenser. Though only one grade of fuel can be selected from a dispenser face at a given time, marketers and consumers alike have found having all grade available at a single fueling point is desirable. Figure 2-9 shows the typical fuel flow through a three hose multiple-product dispenser.

1 Fuel passes through a shear valve then enters dispenser.

2 Fuel flows through a strainer and filter.

3 Filtered fuel passes through a two-stage solenoid and primary valve (earlier models use a check/relief valve and parallel shutoff and slowdown solenoid valves).

4 The meter measures fuel flow.

5 Fuel discharges through the nozzle.

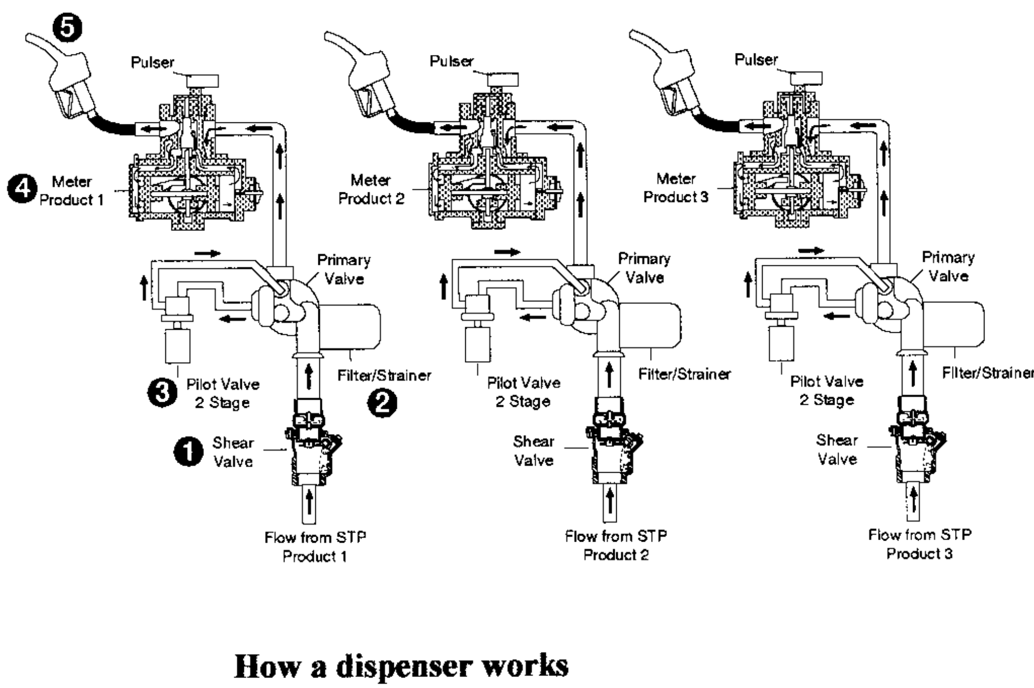


FIGURE 2-9. HOW A MULTIPLE PRODUCT DISPENSER WORKS

With the multiple-product dispenser one set of electronics and one electronic computer controls all hoses on a particular side (fueling point) of that dispenser. A more recent variation of the multiple-product dispenser has been a "single-hose" version. With the single hose version, all grades of fuel come together into a manifold supplying a single hose. Later when we take a closer look at EPO 21, you will see that provision is made for a 0.3 gallon flush before taking a sample for fuel quality testing. Figure 2-10 depicts three grade/three hose and three grade/single hose dispensers.

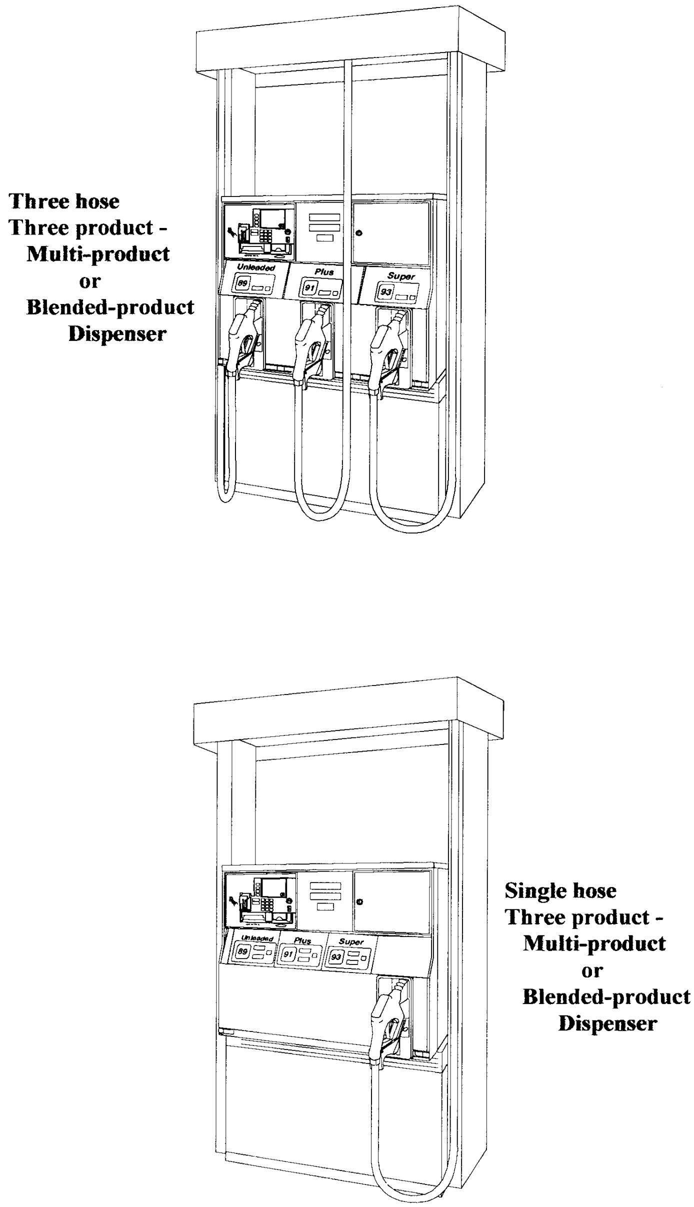


FIGURE 2-10. TYPICAL MULTIPLE-PRODUCT DISPENSER CONFIGURATION

Multiple-product dispensers may be furnished in either self-contained or remote pump versions. The remote pump version is the most popular. With the multiple product pump or dispenser, each grade of fuel has its individual hydraulic system, refer back to Figure 2-9.

Figure 2-11 shows the exterior of several multiple-product dispensers from different manufacturers. The interior configuration of the piping systems as shown in Figure 2-12 is typical of that used in these dispensers.

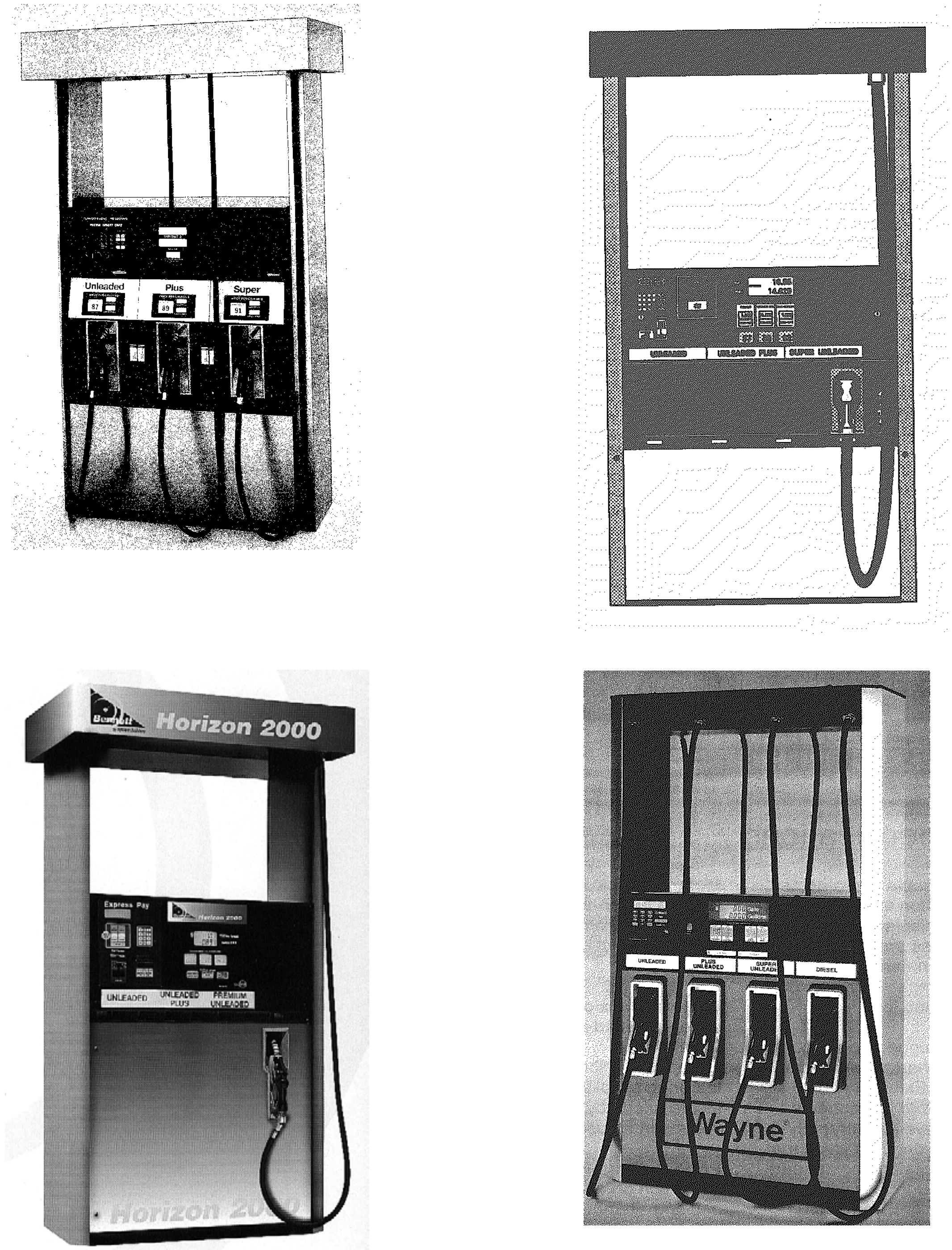


FIGURE 2-11. TYPICAL MULTI-PRODUCT DISPENSER, EXTERNAL

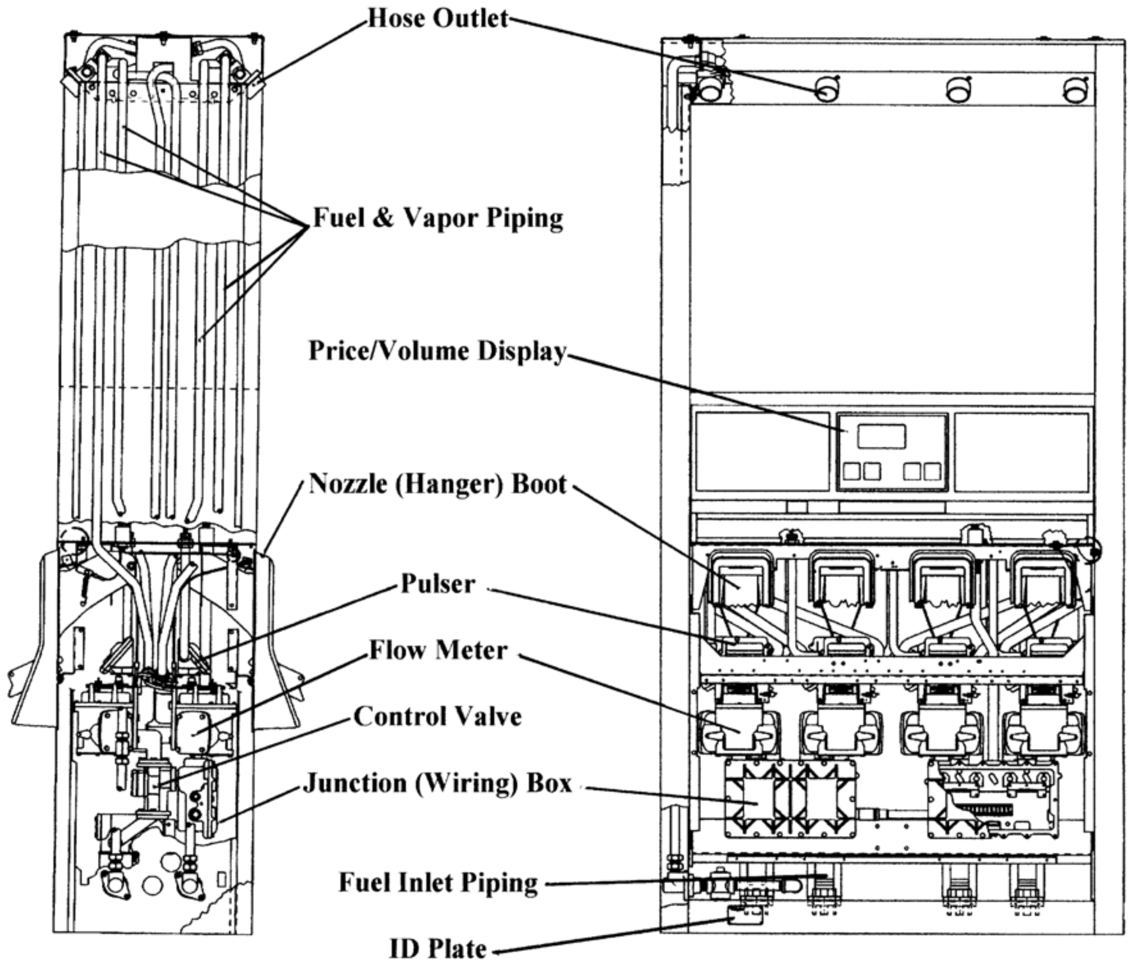


FIGURE 2-12. TYPICAL MULTI-PRODUCT DISPENSERS, INTERNAL COMPONENT

While the interior and exterior of dispensers or pumps from several manufacturers may differ in details of appearance, the basic operation of the dispensers are very similar. With some manufacturers a lever or handle is lifted or rotated to start the dispenser. With other manufacturers pressing a start button or grade selection icon or decal puts the unit into operation. Safety regulations prohibit the dispensing of fuel by merely removing the nozzle from its hang-up position. Another separate action is required, pressing a start button, selecting a grade of fuel, lifting or rotating an operating mechanism, etc.

Blended-product Dispensers

For many years, some retailers have offered blended products, which are produced by blending different grades of the same fuel at the pump. So, for example, a high-octane grade of gasoline can be blended with a low-octane grade in different proportions to produce a number of intermediate grades. (Of course, the component products that are blended must be of the same basic type: different grades of leaded and unleaded gasoline can not be blended.) The customer selects the desired blend by pressing a pushbutton, a grade selection decal, or in the case of older mechanical blenders by operating a control knob or handle.

Like the multi-product dispenser, an obvious advantage of blended-product dispensers is that all product grades can be available at each dispenser, so the customer at a busy station does not have to wait for a pump that carries his or her grade while other pumps remain idle. Another important advantage is that fewer separate storage tanks are required: instead of one tank for each distinct grade, product supplied from two tanks can produce several distinct grades. This latter factor, along with the stricter regulations regarding storage tanks referred to earlier, is likely to encourage more widespread use of blended-product dispensers in the future.

Figure 2-13 illustrates a typical hydraulic system for a fixed ratio blended-product dispenser. This particular illustration shows the fixed ratio valve on the inlet side of the low and high octane product, with the blended output being metered. When the customer selects the high- or low-grade product (by operating the control for that hose), the control valve for that supply is actuated so as to pass product to the meter for the selected product. If the intermediate grade is selected, the control valves are actuated in such a way as to direct supplies of both component grades, in correct proportion for the blend, to a separate meter.

Fixed ratio blender

1 Fuel passes through a shear valve then enters dispenser.

2 For straight product fuel flows directly to a strainer and filter.

3 For blended product fuel flows through strainer/check valve assemblies. These assemblies clean fuel and prevent tank cross flow.

4 Fuel enters blend valve through inlet A and B.

5 The orifices and equalizing piston control flow from each tank. The orifice combination maintains the fixed blend ratio.

6 The fixed ratio fuel flow passes through check valves then mixes in the blend manifold.

7 Straight product and blended product pass through the filter and strainer assembly.

8 Filtered fuel passes through a primary valve controlled by a two-stage pilot valve.

9 The meter measures fuel flow.

10 Fuel discharges through the nozzle

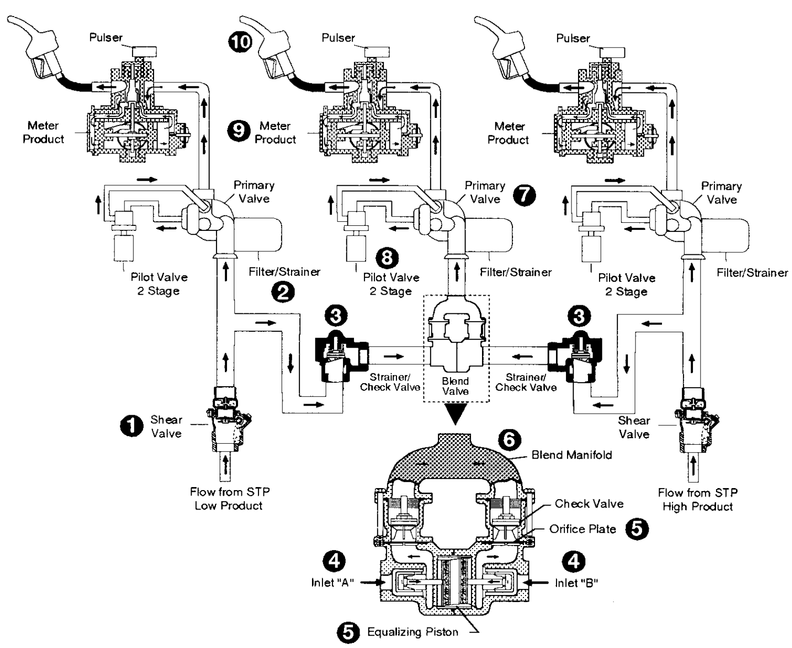


FIGURE 2-13. FIXED BLENDER

A variation is to have the ratio valve on the discharge of the two meters, in this case the computing device, which registers the quantity of the delivery and displays the quantity, total price, and price per gallon, is driven by the component product meters simultaneously. Thus the output of both meters electronically added to give the total blended throughput, and the blended product is not metered. Some fixed ratio blenders use the same electronic proportioning for the intermediate grade as is used by their variable ratio counterpart discussed below.

As will be shown later the dispenser may consist of an individual hose for each product or products may come together at a manifold just prior to the dispenser outlet to the hose and allow for a single hose to dispense any of the products. As mentioned under the single hose multiple-product dispenser, when we take a closer look at the EPOs you will see in EPO 22 that provision is made for a 0.3 gallon flush before taking a sample for fuel quality testing.

Blenders may also be of the variable ratio type and provide, in addition to the two base products, up to three or more (usually a maximum three) intermediate blended products may be delivered from the same dispenser. With the variable ratio blender the use of a single hose is quite common. In some instances a single hose is provided for all the products with an additional hose provided for the highest grade component. Figure 2-14 shows the hose configuration for a three hose blender (top), a system with one hose for the blended products

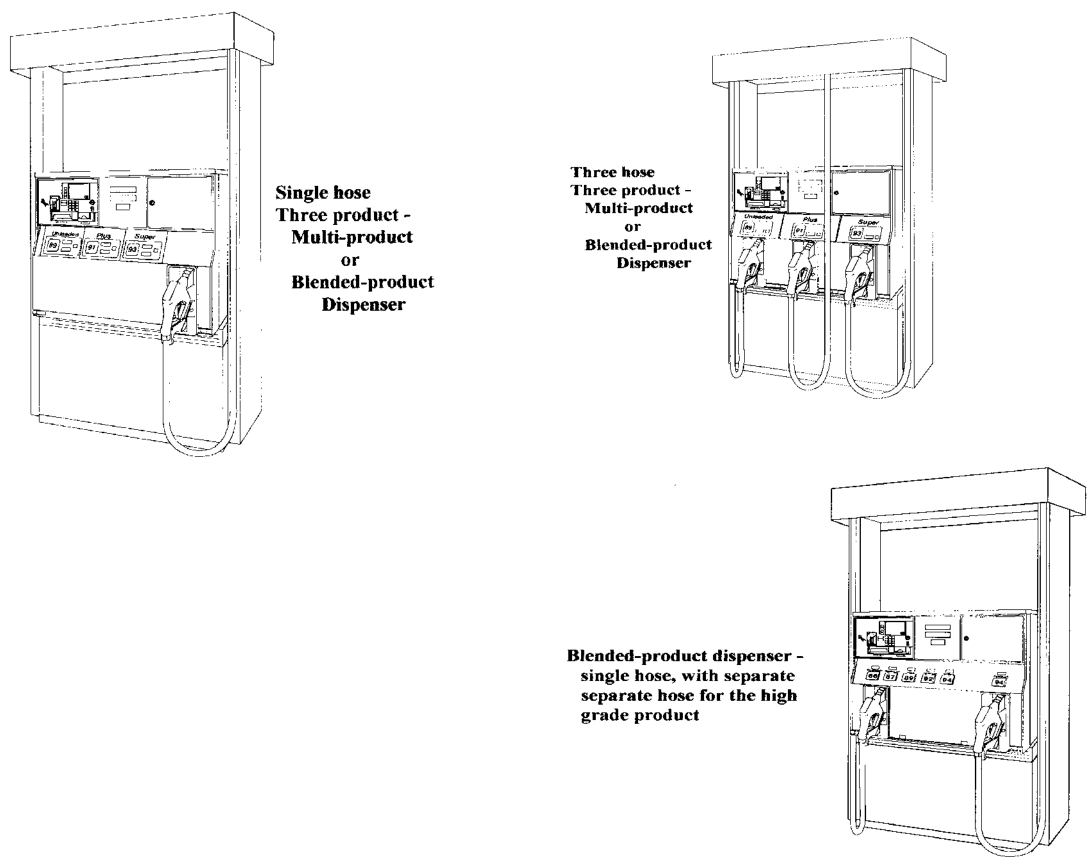


FIGURE 2-14. BLENDER, HOSE CONFIGURATION

and a separate hose for the high octane product (bottom), and a system with a three product blend with single hose for all three products (center). The arrangement shown at the bottom would generally represent a fixed ratio blender configuration.

Figure 2-15 represent single and multiple hose arrangements for several blender types. Without observing the internal piping it is often difficult to determine whether the unit is a fixed ratio blender incorporating a fixed blend ratio valve, a variable blend ratio valve, or whether the unit is a standard multi-product dispenser.

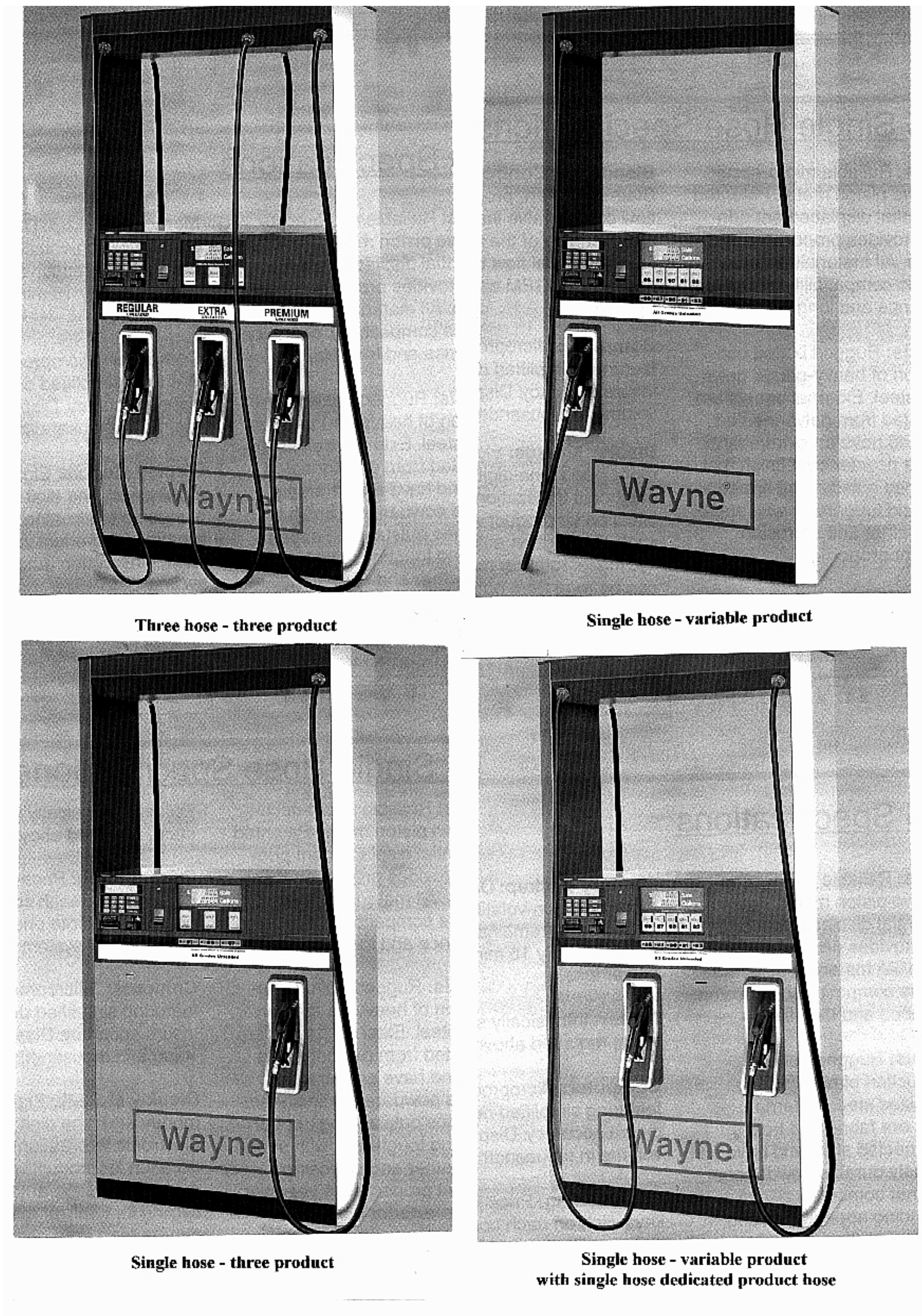


FIGURE 2-15. SEVERAL BLENDER TYPES

Mechanical and Electronic Fuel Dispensers

Currently the majority of new installations are electronic fuel-dispensing systems. Mechanical systems are for the most part found in smaller or older retail outlets. Electronic systems have many advantages that can repay the relatively high cost of investment in a short period of time. The demands of new and expanding marketing concepts can be advanced by electronic technology in relatively short development times.

Because they have fewer moving parts, electronic dispensers generally require less maintenance than mechanical dispensers. They also have high pricing capacity (up to $9.999/gal), another attractive feature, especially in times of frequent and wide fluctuations in fuel prices. And they can register fuel deliveries in very small amounts (thousandths of a gallon, or tenths of one cent) with great accuracy. Too, changes to metric measurement and foreign currency types are more readily handled by the electronic computer.

Another advantage of electronic systems in today's marketplace is that they facilitate multi-tier pricing, the practice of offering the same product at two or more different prices depending upon the delivery and payment method selected by the customer (full serve/self serve, cash/credit), which became widespread in recent years. We will look more closely at the issue of multi-tier pricing in Chapter 5.

Electronic dispensers also have the capability for connection to a variety of electronic input and output devices, like remote readouts, control consoles, and data storage, management, and communication systems. Using these powerful devices, a single attendant can control a number of dispensers at the same time, from a single console installed at a remote location, like an enclosed cashier's station. Readouts on the console show the operator the operating status of each dispenser, the amount of fuel delivered, the price per gallon, and the total price.

In some electronic systems, the operator can pre-set individual self-service pumps to deliver a specific amount of fuel, either by total price or by volume, so that the customer can pay in advance, before filling his or her tank. Many systems can record and store sales data by shift, product, type of sale (cash/credit card), and so on. These data can then be stored electronically at the facility, or transmitted directly to a central data storage facility, located across town, or in another city. Thus the system becomes an invaluable business management tool in addition to serving its function of customer service at the fueling outlet.

The utilization of electronic fuel-dispensing systems with such extended capabilities can reduce labor costs significantly, especially in a large facility, and can also provide greater security and more effective management through enhanced inventory control. And because most electronic systems are modular in design, features can be added to the system without replacing existing equipment.

We will take a closer look at electronic dispensers and control consoles later in this course. To conclude this introduction, let us consider one major difference between mechanical and electronic dispensers that affects the specific requirements that are applied to these devices.

All indicating elements for weighing and measuring devices can be classified as either <u>analog type</u> or <u>digital type</u> devices, as defined in Handbook 44 (Appendix D):

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.

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.

Most mechanical dispensers have analog indicators. Their volume and price indicators are usually revolving wheels, one for each digit, as shown in Figure 2-16. If you observe a mechanical dispenser in operation, you will notice that while fuel is being delivered, the wheels for the smallest amounts (usually cents for price and tenths of a gallon for volume), which have graduations and an indicator, move continuously. So the fuel delivered is being measured and the price computed continuously, even though the amounts are not precisely indicated in the intervals between fixed graduations. For example, the total price wheels in Figure 2-16 indicate a delivery of between $14.06 and $14.07 of product. We could read it with confidence as indicating $14.065: greater precision is limited by the size of the wheel and the fact that the smallest graduated interval is one cent.

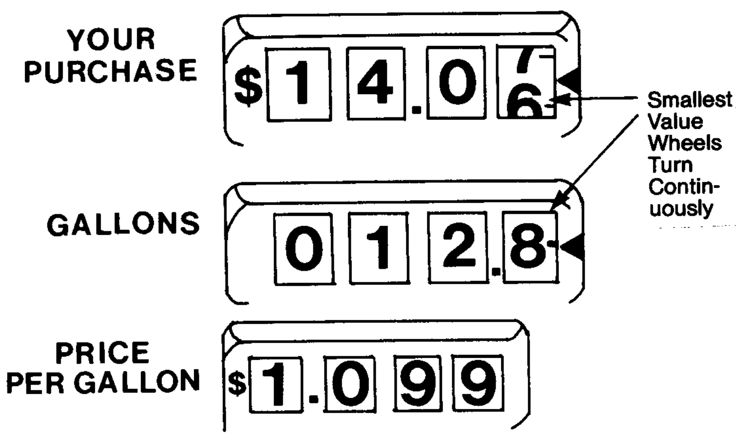


FIGURE 2-16. VOLUME AND PRICE INDICATOR, ANALOG INDICATOR

Electronic dispensers, on the other hand, has digital indicators. When you observe the indicator (like the one depicted in Figure 2-17), usually a liquid crystal or LED display, you will notice that it "jumps" from one value to the next (you may have to operate the pump very slowly to actually see this), even for the smallest amounts (usually cents and thousandths of a gallon) indicated. So, measurements are being indicated intermittently. For example, the indication of 1.476 gallons changes to 1.477 gallons with no intermediate indications.

Analog and digital indicators are equally capable of great—though never truly perfect—accuracy. But because of the difference in the way they indicate measurements, different specifications and tolerances are applied when testing them. We will discuss these further when we turn to actual test procedures, but it is important that you be able to recognize and distinguish between analog and digital fuel-dispensing devices, and that you understand what makes them different.

FIGURE 2-17. VOLUME AND PRICE INDICATORS, ELECTRONIC DIGITAL INDICATOR

SUMMARY

Retail motor-fuel devices are a class of liquid-measuring devices, commonly known as "gas pumps." Design and operating characteristics distinguish them as a class from other similar devices. The fuel-dispensing system consists of three components: the storage tank, pipelines, and dispenser. There are two basic types of systems: self-contained pump and remote dispenser systems. Several different dispenser configurations are in common use (single/dual product, multi-product, blended-product), each appropriate for particular applications. Blended-product dispensers and multi-product dispensers may have separate hoses for each blend (grade) of fuel or they may have separate hoses for each blend (grade) of fuel dispensed. Electronic fuel-dispensing systems are gradually replacing mechanical systems because of their efficiency and flexibility. Analog and digital indicators produce indications of quantities measured and total price in different ways. As a result, different specifications and requirements apply to them, as will be described in detail in later chapters.

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