3.18 Tank Gauges Including Float-Type Tape Gauges


Applications
Tank-farm liquid level detection for accounting purposes and solids level sensing

Types
A. Float operated, wire-guided, inductively coupled
B. Servo-operated float type
C. Surface detector (plumb-bob) gauges
D. Radiation backscatter design (see Section 3.15)
E. Radar tank gauges (see Sections 3.13 and 3.14)
F. Hydrostatic tank gauges, HTGs (see Section 3.6)
G. Hybrid tank gauges

Design Pressure
Surface-detecting solids gauges are used up to 5 PSIG (0.34 bars), standard wire-guided tape gauges are used at 30 PSIG (2 bars), and special designs can be used up to 300 PSIG (20.6 bars)

Design Temperature
Solids level sensors can operate from −4 to 176°F (−20 to 80°C), and tape gauges on liquid tank farms can handle from cryogenic services to up to 300°F (150°C)

Materials of Construction
Mounting flange and housing can be aluminum; wetted parts can be made of aluminum, steel, stainless steel, nylon, PVC, polyethylene, and other plastics or higher alloys.

Electrical Safety
Tape gauges for liquids can be all mechanical or explosion-proof. Inductively coupled float designs are intrinsically safe. The solids level detector plumb-bobs are available in explosion-proof housings.

Range
Standard wire-guided tape gauges are available up to 100 ft (30 m); plumb-bob-type surface sensors are available up to 200 ft (60 m).

Inaccuracy
Error in solids sensors is about 0.2 ft (61 mm); for liquid service automatic tank gauges (ATG) refer to Table 3.18a.

Cost
Plumb-bob solids level sensors start at about $2000. For liquid service automatic tank gauges, refer to Table 3.18a.

Partial List of Suppliers
For the radiation backscatter design, see Section 3.15; for radar tank gauges, see Sections 3.13 and 3.14; for hydrostatic tank gauges, see Section 3.6.
Bindicator (www.bindicator.com) (C, solids)
BinMaster (www.binmaster.com) (C, solids)
Endress+Hauser Systems & Gauging (www.systems.endress.com) (A, B, E, F)
Enraf Inc. (www.enrafinc.com) (A, B, C)
Krohne Inc. (www.krohne.com) (A, B, E)
Monitrol Manufacturing Co. (www.monitrolmfg.com) (A, B, C, E, F)

* I would like to give particular thanks to Frank J. Berto for his many and invaluable inputs on the subject of automatic tank gauging.
In this section, we concentrate on types of automatic tank gauge (ATG) designs that are not detailed in the other sections. The radiation backscatter gauges are discussed in Section 3.15, the radar-type tank gauges in Sections 3.13 and 3.14, and the hydrostatic tank gauges in Section 3.6. For that reason, they will be mentioned only briefly.

**HISTORY OF CUSTODY TRANSFER**

Tank-farm level measurement, particularly in the oil industry, has been the basis for buying and selling products on a volumetric basis. In the 19th century, oil could not be measured more accurately than about 5%, so producers agreed on the size of the 42-gal barrel, thereby making sure that there would be at least 40 gallons in every barrel. A hundred years later, the precision of custody transfer improved to about 0.5% and, today, if every error source except nonuniformity in the tank’s cross section is carefully eliminated, the error will be about 0.25%.

When oil is sold, it can be sold by weight or volume. If sold by the volume, it can be metered or sold on the basis of level measurements. The more advanced and most accurate method is flow metering (see Sections 2.19 and 2.25), which definitely should be used when transferring smaller volumes, and the more traditional is level measurement. One can measure the level manually (which involves climbing to the top of the tank) or automatically, and one can detect the drop in the level of the supply tank (outage) or the rise in the level of the receiving tank (innage). As shown in Table 3.18a, the largest number of existing ATGs are the float-operated tank gauges, which have been used for more than 50 years. They are the least expensive and least accurate and were developed to reduce the need for the operator to climb the tank for manual “dipping.” Here, as shown in Figure 3.18g, a perforated tape runs up from the float to the top of the tank and then down to the gauge head. For this reason, the float-operated ATGs double the reference height error, because the gauge head is mounted at grade. They also require high maintenance because of the moving parts, although the newer designs have fewer of such parts.

**TANK GAUGE DESIGNS**

As can be seen from Table 3.18a, the largest number of existing ATGs are the float-operated tank gauges, which have been used for more than 50 years. They are the least expensive and least accurate and were developed to reduce the need for the operator to climb the tank for manual “dipping.” Here, as shown in Figure 3.18g, a perforated tape runs up from the float to the top of the tank and then down to the gauge head. For this reason, the float-operated ATGs double the reference height error, because the gauge head is mounted at grade. They also require high maintenance because of the moving parts, although the newer designs have fewer of such parts.

**TABLE 3.18a**

<table>
<thead>
<tr>
<th>Features of Automatic Tank Gauges (Based on Reference 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Design</strong></td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Float</td>
</tr>
<tr>
<td>Servo</td>
</tr>
<tr>
<td>Radar</td>
</tr>
<tr>
<td>HTG</td>
</tr>
<tr>
<td>Smart Cable</td>
</tr>
<tr>
<td>Hybrid</td>
</tr>
</tbody>
</table>

Note 1. Costs vary for the different types of Smart Cable systems. A magnetostrictive system for a 40-ft high floating roof tank costs $3500±, including average temperature measurement.

Note 2. The cost, measurement method, accuracy, and maintenance of a Hybrid ATG depends on the level and temperature measurement system. A pressure transmitter adds $1500± to the cost of the system.
In Europe, during the last decades, servo-operated tank gauges have been used for custody transfer level measurement to detect the outage. They, too, should be mounted on a properly supported slotted gauging well to minimize the error caused by reference height movement. Their maintenance has also been improved during the past five years by the development of a new gauge head with fewer moving parts.

As was discussed in Sections 3.13 and 3.14, radar tank gauges can also be used for custody transfer level measurement. They, too, measure outage, so they should also be mounted on a properly supported slotted gauging well. They have no moving parts, so their maintenance is relatively low.
As discussed in Section 3.20, sonic or ultrasonic tank gauges also measure an echo, but their accuracy is affected by vapor above the product, and they have not been widely used for tank measurement in the oil industry.

As already discussed in connection with Figure 3.6e, hydrostatic tank gauges (HTGs) were developed to convert from volume measurement to the detection of mass. HTGs provide mass measurement, limited only by the accuracy of the pressure transmitters and the tank strapping tables. They are not affected by reference height variation, because they measure innage, but the accuracy of their level measurement drops if the tank contents are temperature or density stratified. The smaller and less expensive hydrostatic interface units (HIUs) represent an improvement over the HTGs.

The smaller and less expensive hydrostatic interface units (HIUs) represent an improvement over the HTGs. If a cable containing the level-measuring element runs from the bottom to the top of the tank, it can be called a smart cable. Most types have a float that rides up and down the cable. The best types measure innage, so their accuracy is not affected by changes in reference height, they do not require gauging wells, and (as illustrated in Figure 3.18h) they provide a series of resistance bulbs in the cable to simultaneously measure average temperature. Capacitance tank gauges use two capacitance plates. Capacitance varies with level, because the product dielectric constant differs from that of the air or vapor. Inductive tank gauges measure level using a digital position signal generated by the inductive interaction with a transponder in the float (Figure 3.18i). Magnetostrictive tank gauges measure the time of flight of a torsion wave that pulses up and down a ferromagnetic wave guide, where the wave is reversed by a magnet in the float. Resistive tank gauges (see Section 3.15) use a nichrome helix wrapped around a steel core and covered with a Teflon® jacket. The hydrostatic pressure of the product shorts the helix against the core so that the resistance varies with the product level.

Hybrid level gauges (as illustrated by Figure 3.6e) are still evolving and, in addition to level, can also detect volume, mass, temperature, and density. In this configuration, level and volume are measured by the ATG, and mass is measured by the pressure sensor. The design is still evolving. Hybrids can measure density without sampling or laboratory analysis. Because of the redundant measurements, they also provide some error checking.

**ACCURACY**

According to Berto, quantitatively, the following error contributions can be expected:

1. The error in manual gauging or the ATG is about ±0.125 in.
3.18 Tank Gauges Including Float-Type Tape Gauges

2. The error in the tank capacity tables, including the effect of tank tilt and hydrostatic pressure, is about ±0.5 in.

3. Tank shells expand as a result of liquid head as a full tank takes the shape of a barrel. This effect is normally included in the calculation of the tank tables, but the accompanying movement of the lower datum plate or the upper reference point is not included.

4. Tank bottom movement results in undermeasurement (+0.25 in.). This varies with the compressive strength of the soil under the tank.

5. Incrustation may be significant with heavy or waxy products stored in small tanks. It results in overmeasurement.

6. Movement of the gauging well can be ±1 in. Floating roof tanks should be fitted with slotted gauging wells (Figure 3.18j). Vertical movement of the gauging well movement affects outage measurements and causes an error when converting measured outage to innage.

7. Datum plate movement affects innage measurements by ±0.5 in. When a tank is filled and the shell takes a barrel shape, the bottom bulges up adjacent to the shell. Farther inward, the bottom moves down because of hydrostatic pressure. The datum plate should be located 18 to 30 in. from the shell to minimize the effect of bottom movement.

8. Thermal expansion of the tank shell and the gauging well can amount to ±0.125 in. Thermal expansion causes two errors, because both the tank diameter and the tank height change. Tank capacity tables are calculated for one temperature (60°F). They do not correct for the thermal expansion of the tank shell. The amount of error depends on the product temperature and the ambient temperature.

9. Another serious source of errors is poor temperature measurements. With heavy oils, it takes 45 min for a manual temperature measurement using a cup-case, even if the thermometer is continuously moved up and down. This can result in 2 to 3° of error. ATGs are provided with high-performance average temperature sensors, but at a cost of about $2000.

10. In crude oil level measurement, a major error source is the method used in determining the sediment and water content of the oil. Manual sampling is unacceptable,
because it does not provide a representative sample and does not necessarily analyze the sample correctly. Therefore, automatic samplers are recommended.

**TRADITIONAL TAPE LEVEL SENSORS**

Tape level detectors can be furnished with local or remote readouts and can facilitate inventory control in multiple tanks and silo installations. Liquid level detector tape gauges include the conventional tape gauges (a wire-guided float or displacer), the inductively coupled float, and the wire-guided thermal sensor. The surface-sensing tape gauges (plumb-bobs) used in solids service have a resolution of about 0.1 ft (30 mm) and an error of about 0.2 ft (60 mm). This accuracy on solids level measurement is usually acceptable, as other variables (such as changes in the angle of repose, bridging, rat-holing, and the change in the shape of solids level as the operation is changed from filling to discharging) all cause errors in the correlation between level and volume. As a result of these uncertainties, very precise measurement of the level at a particular point is of no great value.

**WIRE-GUIDED FLOAT DETECTORS**

Figure 3.18k shows a wire-guided float detector that has a tape connection to a ground reading assembly. This detector has evolved from the float-operated gauge board. The system shown here is suitable for tanks having an operating pressure to 30 PSIG (0.2 MPa) and a height of up to 60 ft (18 m), although other designs are available that are rated to 300 PSIG (2 MPa). The float is about 15 in. (381 mm) in diameter and can be made of aluminum, stainless steel, or other alloys; it can be hollow or filled with materials such as foam glass. To direct the float, guide wires are connected to top and bottom anchors. The top anchors are normally spring loaded to maintain constant tension on the wires; the bottom anchors are tank clips.

A tape runs from the connection on the top of the float, over sheave assemblies, and down to the gauging head, which is outside the tank at eye level. The detail in Figure 3.18k shows the tape passing through an oil seal assembly. This seal can be used for gauge head corrosion protection or to prevent product condensation in the head, provided that the tank is operated at very close to atmospheric pressure. If the tank is pressurized, it is usually desirable to fill the head with the product, particularly if the product is clean and lubricating.

The tape, which is perforated, enters the gauge head, runs around a sprocketed counter drive, and is taken up on the tape storage reel. Tape tension is maintained by a secondary (spring-wound) take-up device. The shaft on the counter drive rotates as the float moves the tape up and down, and, by proper gearing, this rotary motion can be used to drive a feet-and-inches or metric readout. The counter is located outside of the gauge head, preventing exposure to any liquid fill in the head that may be present.

For lower-pressure designs, the shaft extends out of the gauge head through a gland, whereas, for pressures above 30 PSIG (0.2 MPa), the shaft motion is normally taken out of the head through a magnetic coupling. The gauge head can be equipped with several optional devices. A crank assembly mounted on the head permits lifting the float out of the process. Material buildup on the float that hinders smooth operation may make this necessary. Often, the float can be freed by lifting and lowering it. The head also may be equipped with a variety of switch configurations for high and low level alarms or for control-circuitry actuation.

Figure 3.18b shows installation details for wire-guided floats in low-pressure tanks. Figure 3.18l shows a high-pressure installation rated to 300 PSIG (2 MPa). At the higher pressures,
3.18 Tank Gauges Including Float-Type Tape Gauges

The flat, circular float design is no longer suitable, and one or more spherical floats are used. Connections for a high-pressure installation should be flanged, including those for the top anchor assemblies. Another feature to note in Figure 3.18l is the gate valve with rubber plug that is installed at the tank entry, allowing removal of the gauge head without tank depressurization.

One common problem with these level devices is tape hang-up. This can occur if the long guide pipes are not perfectly vertical and the tape rubs against the inside of these pipes. If dirt or corrosion is also present, the resulting friction can hold the tape in place while the float is moving. This has caused accidents in cases where tanks controlled using tape level gauges overflowed because the tape was stuck. One recommended precaution is to install a separate high-level switch.

Another recommended precaution is to use a microprocessor-based tank-farm operations controller as an added level of safety (Figure 3.18m). This unit controller can continuously monitor all operations that occur on the tank farm. It knows the capacity of each tank and the pumping rate of each pump, so it can check whether, under a particular filling operation, the level in the tank should be rising at a particular rate. If it should not (because the level transmitter is defective), the controller can sound an alarm or shut the system down.

**Encoding**

The wire-guided float detector level must be converted to an electrical signal by using the shaft rotation of the gauge head to drive encoding discs. Figure 3.18g illustrates one conversion method. The input shaft drives the “inches” wheel, and the gear assembly at the left of the sketch drives the “foot” wheel. For purposes of this sketch, the level tape sheave and shaft are set up to rotate 180° for each foot of level change. As the inch wheel completes one-half of a revolution, it steps the foot wheel up or down, corresponding to rising or falling level. Stepping of the foot wheel occurs when the notches on the inch wheel pass the gear. The wheels are coded so that a rotation corresponding to a 0.01-ft level change presents a new and unique digital code to the code take-off assembly. Codes are available for foot, inch, and fraction, or meter and millimeter readouts. Since the principle of operation is the same for all, only the foot, tenths, and hundredths will be covered.

The wheel has a number of concentric tracks on it, each track representing one digit of the digital word. The tracks are designed to produce the zero or one information needed for the digital word. This can be done in several ways. One way is to plate portions of the track with a conductor and allow a conducting brush to ride on the track. If the brush is on a conducting portion of the track, a current path will be formed, and a one will be produced. If the brush is on a nonconducting part of the track, the current path will not be formed, and a zero will be produced. Another encoding method is to use optical coupling. Portions of the tracks are plated with a reflecting material, and a light is beamed on the tracks. If the beam hits a reflecting portion of the track, a light-sensitive transistor conducts, thereby producing a one. If the beam hits a nonreflecting portion, the transistor does not conduct, and a zero is produced.

Figure 3.18n shows how a modified gray code could be used to produce a digital word that is unique for a given wheel position and thus a given level. (Only 8 tracks are shown instead of the 16-track arrangement that would be required for a ±0.01-ft (0.3-cm) resolution over an 80-ft (24.3-m) span. Also, the tracks are shown as being linear whereas, in the actual configuration, they would be on closed circular tracks. The shaded areas represent conducting portions of the tracks, and the light portions are nonconducting. Thus, if the float were at a level corresponding to 6.4 ft, the code produced would be 10100110. The digital code is produced continuously. It is read by the remote device when the tank gauge is addressed as described in the preceding paragraphs.

**FIG. 3.18m**
The use of tank farm unit controllers increases the safety of operation.

**FIG. 3.18n**
Encoding with a modified gray code.
Temperature Compensation

Because liquids expand when heated, variations in the temperature of the material in the tank will affect the level reading. For this reason, it is quite common to take a temperature measurement of the liquid at the same time that the level is gauged, using the data to make a level correction based on temperature change. Equipment is available to accomplish this automatically. The resistance temperature detector (RTD) sensors at the various tanks can be switched into the remote readout at the same time that the level measurement is being made, using the same type of wiring arrangement shown in Figure 3.18i. A wide array of remote temperature and level readout equipment is commercially available. The simplest is the manually operated unit with pushbutton random access to all tanks. These units generally display the number of the tank called, its level, and its temperature. The more complex systems are microcomputer or minicomputer based and can have automatic logging of temperature-compensated level plus other features such as high and high-high-level alarm. Most systems can be readily interfaced with larger computers.

**INDUCTIVELY COUPLED TAPE DETECTOR**

Figure 3.18h illustrates a fixed tape, float-actuated level measuring device. The tape is suspended from the roof of the tank and is anchored to the bottom. The tape is used to guide a float that contains an inductively coupled transducer. The tape consists of a steel ribbon and a number of insulated conductors encapsulated in a Teflon jacket. In addition to providing mechanical strength, the steel tape is used to provide power to the transducer in the float through inductive coupling. At short intervals, this primary coupling is interrupted, and a secondary inductive coupling from the transducer to the conductors on the tape is established.

The conductors are arranged on the tape in coded patterns so that each 0.1-in. (2.5-mm) increment has a unique code. The receiver mounted at the top of the tank reads which conductors have been inductively coupled. From this information, it can determine where along the tape the float is located and thus the elevation of the liquid level. The float is Teflon coated, and the tape-to-float clearance is approximately 0.25 in. (6.3 mm) to minimize float sticking and material buildup on the tape. The receiver can be furnished to transmit an analog signal proportional to level, or it can transmit the digital signal that has already been produced by the tape-and-float assembly, which has a resolution of 0.1 in. (2.5 mm).

The conductors on the tape are arranged to produce a gray code digital word. In the gray code, only one digit in the word changes from one word to the next, so only one conductor must change its position from one 0.1-in. (2.5-mm) increment to the next. The number of conductors required increases with the span of the liquid level to be measured. The span covered is equal to $2^N$, where $N$ is the number of conductors. Thus, if four conductors are used, the span would be 16 increments, or 1.6 in. (40 mm). If 14 conductors are used, the span would be 16,384 increments, or 135 ft (41 m). In addition, each system requires a reference conductor and a return conductor.

Figure 3.18i describes, in schematic form, how four conductors might be arranged on the steel tape to produce the gray code digital word for a 16-increment measuring system. If the conductor is on the right-hand side of the tape, it is inductively coupled to the transducer in the float; if on the left, it is not. The reference wire tells the receiver which side of the tape is the right-hand side. The return conductor is common, completing the circuit for all conductors. As shown in the figure, if the float is at increment 7, conductors 1 and 2 will be inductively coupled, and conductors 3 and 4 will not. Thus, the gray code digital word produced is 0011, which is unique for the particular increment. As previously noted, each additional conductor doubles the preceding span; adding a fifth conductor to the arrangement shown in Figure 3.18i would enable measurement more than 32 increments; a sixth conductor would enable measurement over 64 increments, and so on.

The inductively coupled tape level system is intrinsically safe. In addition to accurately measuring the level, it can also determine the density of the process fluid and, based on that information, calculate the mass of the tank contents. Sensors are also provided for pressure, temperature, and interface measurement.
WIRE-GUIDED THERMAL SENSOR

Because liquid conducts heat better than does vapor, the liquid surface is bracketed by the two vertically displaced sensors. The lower one is cooler than the upper one. Figure 3.18p gives an installation detail for a wire-guided thermal sensor. The sensor, which is heavier than the liquid being measured, is suspended from an armored control cable and guided by a wire attached to the top and bottom of the storage vessel. The control unit detects the position of the sensor relative to the liquid level and issues step-up or step-down commands to the control cable take-up wheel until the lower sensor is in the liquid and the upper sensor is in the vapor. The system remains at rest as long as these conditions are met. When the sensor is moving, each stepping command adds or subtracts a length unit from the previous controller reading so that sensor position, and thus level, is accurately known.

The unique feature of this instrument is that the sensor is heavier than the liquid, allowing the unit to be lowered to the tank floor so that the control and counter circuitry can be zeroed. The controller contains a cable tension sensor to signal when the level sensor has hit bottom. A controller subroutine permits automatic zeroing. The sensor also can be equipped with a temperature detector to provide a thermal profile of the tank material. This is useful for accurate correction of level measurement and can also be used to detect temperature inversions in cryogenic services.

SOLIDS LEVEL DETECTORS

Although the gauges described here were originally developed for solids level detection, they can also be used for liquid level detection if equipped with a properly designed sounder. As shown in Figure 3.18q, a sounder is suspended from the winding drum. The wire tension is continuously detected by the weight balance. A reversible servomotor rotates the drum when a starting signal is received, and it releases the wire until the sounder strikes the solid (or liquid) surface. When this occurs, the tension in the wire slackens, causing the weight balance to actuate a microswitch. After the momentary slackening of the cable, the microswitch reverses the motor and returns the sensing bob to its original reference position.

The shape of the sensing bobs (or sounders) varies with the process fluid. Figure 3.18r illustrates some of the typical shapes used on both liquid and solids services. On solids with less than 20 lbm/ft³ (320 kg/m³), the type A sensing bob is used. For higher densities, the type B is recommended, and, for coarser solids, the type C design is the appropriate choice.

A pulse generator is coupled to the system to provide an input signal to the counter, which counts down from a preset maximum reference value in steps. When the sounder strikes
the product surface, the solids level is displayed and, at the same time, the counter is automatically disconnected from the pulse generator. The reading stays on the counter until the next measurement. On receipt of a new start signal, the counter is reset to the maximum reference value, and the measurement cycle is repeated. There are several ways in which the amount of cable paid out can be converted to pulses. In one design, the cable pays out over a measuring wheel with a 6-in. diameter. The measuring wheel drives a five-lobe cam that trips a stationary cam each time a lobe passes by. In this way, ten contact closures are produced for each foot of cable paid out.

In another, higher-resolution design, the measuring wheel drives a disc that has 50 radial slots around its circumference. Here, the slots are counted by a light beam and a light-sensitive transistor, and 100 pulses are generated for each foot of cable “paid out.” In either case, the level measurement reference is the top of the tank.

In dust-filled atmospheres, a solenoid-operated pneumatic cleaning assembly should be added to ensure reliable operation. As shown at the top of Figure 3.18s, the relative locations of the gauge nozzle and the solids inlet nozzle are important, because the sounder is used to take an average level reading. At no time should there be any contact between the filling system and the sounder. If the inlet nozzle is in the center of the bin, the surface of granular products will tend to take the shape of a cone. The gauge, therefore, should be located to obtain an average level. As shown in the sketch, this requires the nozzle to be one-sixth of the diameter from the bin wall for circular bins. The sketch on the bottom of Figure 3.18s shows the proper location for installations in rectangular bins.

**CAPACITANCE AND DISPLACER TAPE DEVICES**

At least two other tape level detector designs are available. In one, the sensor is suspended on a cable and held a short distance above the liquid level. The distance is sensed by a proximity-type capacitance probe (Figure 3.3f). The control unit monitors the capacitance between the sensor and the liquid level, repositioning the sensor as the level changes. Sensor position, and thus level, is determined by measuring the amount of cable that has been paid out. In this respect, it is the same as the wire-guided thermal sensor previously described.

The second design uses a displacer mounted on the end of a cable. In this design, the displacer is continuously repositioned so that it is always immersed the same amount, say, to 50% of its 0.1-in. (2.5-mm) thickness. Level is determined by the amount of cable paid out. The displacer design uses a displacer mounted on the end of a cable. In this design, the displacer is continuously repositioned so that it is always immersed the same amount, say, to 50% of its 0.1-in. (2.5-mm) thickness. Level is determined by the amount of cable paid out. The displacer design has cable weight compensation but is not compensated for changes in liquid density. Both the capacitance and the displacer designs are installed in stilling wells.

**MULTIPLE-TANK SYSTEMS**

As previously mentioned, gauges covered in this section are used in conjunction with remote manually operated and automatically operated multiple-tank gauging systems. Multiple gauging requires cables from each tank to the remote readout. For wire-guided float detectors, the shaft position on the gauge head must be transduced to an electrical signal. The objective in designing the cable system is to wire up all the tank gauges with as few wires as possible, which means that wires must be shared.

**Figure 3.18o** shows a wiring system used to obtain a level reading for any one of five tanks. Eight wires are used. By closing the tens switch #50 (at the top of the figure), one-half of the circuit to the relays at tanks 50 through 54 has been closed. Closure of any unit switch #00 through #04 will complete a circuit through the relay coil associated with the tank that is to be remotely metered. In the figure, switch #02 is closed; therefore, relay R-52 is energized, and relay contact R-52A is held closed. The remote readout can now obtain the level data that is available at the gauge head at tank 52. This technique allows a great number of tanks to be remotely monitored with relatively few wires. For example, a 100-tank installation can be monitored using 22 wires. The 22 wires would be composed of 10 for the tens position, 10 for the units position, and 2 for the signal. A second group of 100 tanks can be picked up by adding only two more wires, one for the 100s-series tanks and one for the 200s-series tanks.

When the distance from the tanks to the remote readout is long, a satellite multiplexer may be considered. The satellite multiplexer collects level information for tanks in the immediate vicinity and transmits it, on demand, over two wires to the remote readout. The satellite multiplexing system might be used for a pipeline transmission installation where the various bulk storage facilities are hundreds of miles apart.

The switches shown in Figure 3.18o constitute a manually operated multiplexer. These switches can be operated by a data logger or by a computer, making inventory monitoring completely automatic.
The reason for monitoring a tank farm with as few wires as possible is to reduce installation costs. In so doing, the gauge head relays and much of the wiring are run in parallel. This means that a short to ground, an open wire, or a malfunctioning gauge head can disrupt the entire system. Many tank farms are located in corrosive and/or humid environments. Therefore, particular care should be taken in the design and installation of the cable system, especially at the terminals in the gauge heads and junction boxes. Lightning strikes can be another source of trouble, given that most tank-farm cabling systems are run overhead. Surge protection should be installed at each gauge head and at the remote readout. Associated loggers and computers should be electrically isolated. As an aid to troubleshooting a crippled system, isolating switches should be installed so that blocks of gauges can be separated from the system to enable a more rapid location of the fault.

CONCLUSION

Flow meters and provers offer the most accurate ways to measure standard volumes of liquids. Tank measurement is much more inaccurate when measuring small parcels. In custody transfer of full or nearly full tank volumes, manual gauging is preferred in the U.S., and ATGs are preferred in Europe. In either case, the inherent tank accuracy is a factor, because the filling of a large tank causes the bottom to sink, the shell to bulge, and the top to sink, and changes in temperature also cause changes in tank dimensions.

Automatic tank gauging systems are found in almost all tank farms of any size. They enable inventory monitoring at a given time each day. The wire-guided float tape gauge systems are most common on the existing tank farms (Table 3.18a) on liquid services. The design of the remote metering portion of these systems has been improved markedly over the past years, and these systems can be expected to perform satisfactorily if they are properly installed and maintained. To protect against tank-farm accidents such as overfilling, they should be backed up with high-level switches, and computer monitoring should be provided to detect for sensor failures resulting from float or tape hang-up.

The inductive tape-and-float systems and the wire-guided thermal capsule systems are more expensive and do not have as great a degree of field exposure as the wire-guided float types. (Table 3.18a). However, the tape-and-float system has fewer moving parts and therefore requires less maintenance. The wire-guided thermal capsule can be zeroed and can also be used for temperature profiling. Some users regard the in-tank electrical circuitry required by these latter designs as a drawback, but intrinsically safe designs should alleviate that concern.

The surface sensor design has been used for some time for solids level measurement. There have been reports that the sensor can become buried or detached from the take-up cable, contaminating product or ruining downstream equipment. A more rugged cable and sounder design should overcome this problem. The surface sensor is not highly recommended for liquid level applications, but it is acceptable for solids level measurement if an error of a couple of inches is acceptable.

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