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In This Issue

John Parker, Editor

E. W. Hoyer, Technical Editor

WESTON ELECTRICAL INSTRUMENT CORP.,
614 Frelinghuysen Avenue,
Newark 5, N. J., U. S. A.

ADJUSTMENT OF WESTON SWITCHBOARD WATTMETERS AND VARMETERS

SWITCHBOARD wattmeters and varmeters are generally used with external current and potential transformers to measure watts and vars. To adjust the instruments independently, it is necessary to compute the full scale wattage adjustment from the known scale range, transformer ratios and connections.

In the simple case of a single-phase wattmeter connected in single-phase two-wire circuit with transformers, the wattage adjustment of the instrument itself is equal to the scale range divided by the transformer ratios. For example, the adjustment of a wattmeter having a 5-kw scale and using a 460:115-volt potential transformer and a 10:5-ampere current transformer is:

$$\text{Full scale} = \frac{5{,}000}{4 \times 2} = 625 \text{ watts}$$

Since the transformers are range extenders, and multiply the instrument range by their ratios to give the scale range, the adjustment is the reverse of this or the scale range divided by the transformer ratios.

The instrument can be adjusted by connecting it directly to a 625-watt load along with a suitable wattmeter as a standard, or it can be adjusted by passing a current through the current circuit and impressing a voltage across the potential circuit with the current and voltage kept in phase with each other and their product equal to the wattage adjustment. This is easily done with direct current since Weston switchboard wattmeters are of the air core electrodynamometer type and indicate accurately on either a-c or d-c. The latter method is used in the Weston Laboratory since any range instrument can be adjusted using the same standards as used for calibrating ammeters and voltmeters.

Safe adjustment limits have been set for all voltage and current circuits of switchboard wattmeters and varmeters. Most of these instruments have a normal rating of 115 volts, 5 amperes. The adjustment wattage for a single-phase wattmeter has been established for this rating at 460 watts minimum and 750 watts maximum. The limits for other voltage and current ranges are in proportion to the 115-volt, 5-ampere values. For example, the limits for a 230-volt, 5-ampere instrument are 920-1,500 watts and for a 115-volt, 2.5-ampere instrument are 230-375 watts. Also, when the zero on the scale is at other than end scale, the same limits apply to the total scale; that is, the sum of the two end scale adjustment watts must be equal to or greater than the low limit and the greater end scale adjustment watts must be equal to or less than the high limit.

The low limit is required to limit the current in the moving coil and series resistance to safe values. If the adjustment wattage is allowed to go too low, the series resistance will decrease to a point where the moving coil and series resistance may become overheated in use. Where the power factor of the circuit is low and it is necessary to adjust the wattmeter to a value below the safe limit, the series resistance can be increased by using more turns on the field coils, although this procedure does limit the current overload capacity.

The high limit was chosen to prevent overloading the current circuit. A 5-ampere, 115-volt instrument adjusted to 750 watts will require 115 volts and 6.52 amperes at unity power factor for full scale deflection.

If the power factor goes below 65 per cent, more than 10 amperes will be required for full scale deflection at 115 volts. Since this is greater than the safe overload of 100 per cent, field coils having a higher normal rating are used for such applications so that the adjustment comes within the limits set for the higher range field coils.

The same limits apply to single-phase varmeters with the adjustment in vars computed in the same manner as for the wattmeter.

Single-phase wattmeters used with two current transformers in a single-phase three-wire circuit with balanced voltages require special consideration. Referring to Figure 1, it can be seen that the current transformers are connected so that the sum of the secondary currents will flow through the instrument field coils. This current may be twice the normal secondary current from each transformer for balanced load. Hence the current circuit rating should be 10 amperes normal when used with 5-ampere current transformers. When computing the adjustment, the current transformer ratio is equal to the primary rating divided by twice the secondary rating, since the secondary currents add.

For example, assume that a single-phase wattmeter having a range of 230 volts and a scale of 20 kw is connected to a single-phase three-wire system using two current transformers each having a ratio of 100:5 amperes. The current transformer ratio is $\frac{100}{5\times 2}$ or 10. The adjustment is then $\frac{20{,}000}{10}$ or 2,000 watts. The instrument will have a rating of 230 volts, 10 amperes normal and the adjustment of 2,000 watts is within the limits of 1,840-3,000 watts (four times 115-volt, 5-ampere values) set for this rating.

One-Element, Three-Phase Three-Wire Wattmeters and Varmeters

A single-element wattmeter is often used to measure the power of a balanced three-phase three-wire system. This can be done by means of a three-resistor network connected to form an artificial Y with the potential circuit of the instrument as one section of the network. The other two sections each have the same resistance as the instrument, and the voltage across the instrument is then equal to the phase voltage or voltage to the artificial neutral. The current circuit of the instrument is connected in the same line as the potential circuit and the instrument indicates the power of one phase. The instrument is scaled in terms of the three-phase watts which is three times that of one phase. When computing the adjustment watts, it is necessary to divide the scale range by three as well as by the transformer ratios. The adjustment limits and adjustment are the same as for the single-phase instrument having a potential rating equal to the phase voltage. The potential circuit resistance of the instrument is measured after the instrument is adjusted, and the two resistors forming the remainder of the network are each made equal to this resistance.

It also is possible to measure the power in a balanced three-phase three-wire system by connecting a single-element instrument to two current transformers connected as shown in Figure 2. The voltage measured is the line voltage and the current measured is the line current times $\sqrt{3}$. Since the three-phase power is $\sqrt{3}$ times the product of the line voltage, line current, and the power factor, the adjustment wattage is equal to the scale range divided by the product of the transformer ratios. Note that the current rating of the field coils should be increased to 10 amperes when 5-ampere transformers are used and the adjustment limits of the 10-ampere single-phase instrument will apply. Adjustment is done the same as for the single-phase instrument.

A single-element instrument can be used to measure the vars in a balanced three-phase three-wire system by connecting the potential circuit across lines 1 and 3 and by connecting the current circuit in line 2. Since $\sqrt{3}$ times the product of line voltage, the line current and $\sin\phi$ is required for three-phase vars and since the instrument measures the product of line voltage and the line current, the scale range must be divided by $\sqrt{3}$ as well as by the transformer ratios to obtain the adjustment. The instrument is adjusted the same as the single-phase wattmeter and the same adjustment limits apply.

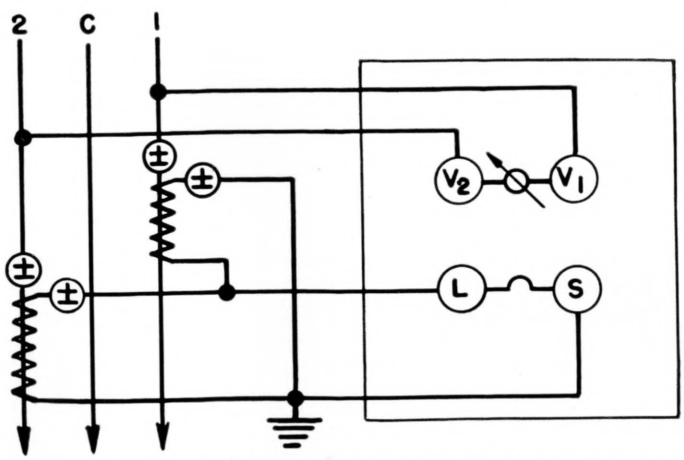


Figure 1—One-Element Wattmeter connected to a Single-Phase Three-Wire System by means of Two Current Transformers.

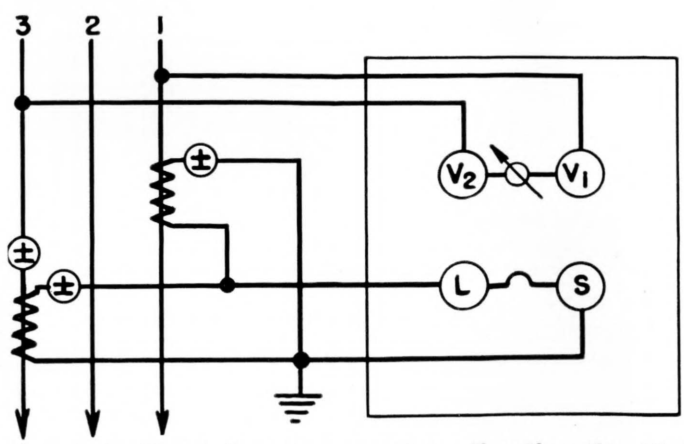


Figure 2—One-Element Wattmeter connected to a Three-Phase Three-Wire System by means of Two Current Transformers.

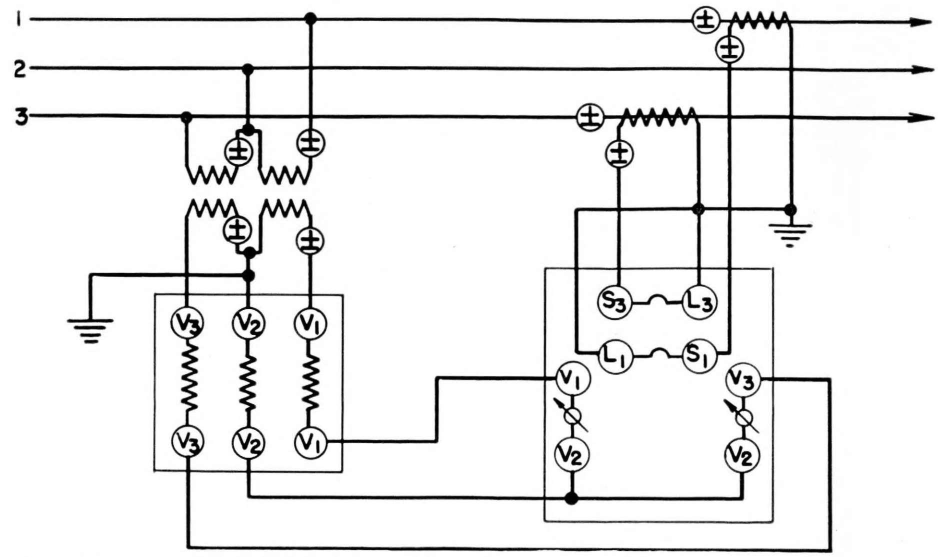


Figure 3—Two-Element Varmeter connected to a Three-Phase Three-Wire System by means of Y Resistor Network and Two Potential and Current Transformers.

Two-Element, Three-Phase Three-Wire Wattmeters

Two-element, three-phase three-wire wattmeters are treated in the same manner as single-phase instruments. The adjustment in watts is equal to the scale range divided by the transformer ratios. The adjustment limits are higher than the single-phase instrument and are 725 watts minimum, 1,500 watts maximum for the 115-volt normal, 5-ampere normal instrument. When the zero is at other than end scale, the sum of the two end scale adjustment watts must be equal to or greater than 725 watts and the greater end scale adjustment must be equal to or less than 1,500 watts. The limits for other ratings are in proportion to the current and voltage ratings. The reasons for these limits are the same as for the single-phase wattmeter.

Each element of the two-element wattmeter is adjusted separately to the full value of watts computed for the adjustment. As an example, suppose a two-element wattmeter with a scale range of 800 kw is connected to a three-phase three-wire system using two potential and two current transformers having a rating of 2,300:115 volts and 200:5 amperes. The adjustment is then:

$$\frac{800{,}000}{20\times 40}=1{,}000 \text{ watts}$$

Each element is then adjusted separately to full scale by connecting it to a 1,000-watt load or it can be adjusted by applying a d-c voltage of 100 volts to the potential circuit and by passing a direct current of 10 amperes through the current circuit. The polyphase adjustment can then be checked by connecting the instrument to a 1,000-watt polyphase circuit or it can be checked on direct current by connecting the potential circuits in parallel and the current circuits in series and applying 100 volts and 5 amperes. This is the equivalent of 500 watts per element or 1,000 watts total which is the adjustment watts. The polyphase adjustment can also be checked using a single-phase load of 500 watts by connecting the potential circuits in parallel and the current circuits in series as done for the direct current test.

Two-Element, Three-Phase Three-Wire Varmeters

Two-element, three-phase three-wire varmeters used with combined phase shifting and autotransformers are identical to the wattmeters except the scale caption is in vars. The adjustment is computed in the same manner and the instrument is usually adjusted without the phase shifting autotransformer to the equivalent value of watts since this transformer supplies the same value of voltage at a 90° phase angle from the voltage used when the instrument is connected as a wattmeter.

When the two-element varmeter uses a special resistor network to supply the voltage of the proper phase (see ENGINEERING NOTES, Volume 3, Number 3, Page 5, Figure 13), a special adjustment has to be made. The adjustment watts are computed the same as for the wattmeter and the value must come within the limits given for the two-element wattmeter. The adjustment is then multiplied by $\frac{1}{\sqrt{3}}$ since phase voltage is being used instead of line voltage. Each element of the varmeter is then adjusted the same as for the two-element wattmeter using the computed value of adjustment watts. A third resistor is then adjusted to the average value of the total resistance of each element and is connected to the resistors and moving coils of the two elements to form an artificial neutral as shown in Figure 3.

As an example, assume that the wattmeter specified previously is to be supplied with a scale of 800 kv and used with the same potential and current transformers. The adjustment is then 577 watts. Each element is adjusted to this value and the total potential circuit resistance is found to be 1,400 ohms for one element and 1,450 ohms for the other element. A third resistor is then adjusted to 1,425 ohms and connected as shown in Figure 3.

Two and One-Half Element, Three-Phase Four-Wire Wattmeters

The adjustment of two and one-half element wattmeters is computed in the same manner as for the one and two-element wattmeters. The limits for the 115-volt, 5-ampere normal instrument are 1,450 to 3,000 watts, and have been established as described for the one-element wattmeter.

The adjustment of these wattmeters is more complicated than the two-element type since it is necessary to adjust three elements. These three elements consist of an upper field coil and moving coil, a lower field coil and moving coil, and an upper and lower field coil connected in series and acting with the same two moving coils. (See Figure 4.) All field coils have the same number

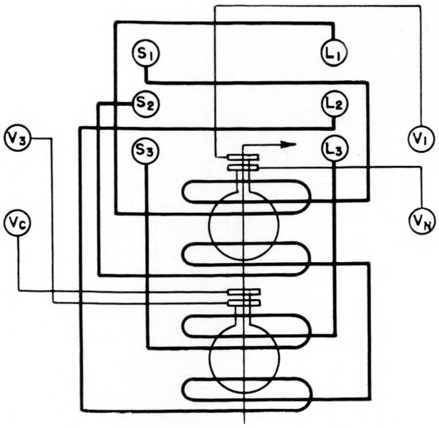


Figure 4—Internal connections of 2½-Element Wattmeter.

of turns and if any one field coil and its adjacent moving coil is checked with the full adjustment watts, full scale deflection will be obtained. If two field coils and their moving coils are energized then one-half the adjustment watts are required for full scale deflection, and when all field and moving coils are energized one-quarter the watts are required. The actual adjustment is done the same as for the two-element wattmeter for the upper and lower elements using the one field coil. The element using the two field coils in series is then checked with both moving coils energized and with half the adjustment watts. It may be necessary to respace the field coils if full scale deflection is not obtained under this test since the only adjustment for this element is to move the field coils closer to or further away from the moving coils. During the adjustment it is necessary to overload the field coils beyond their maximum rating to obtain full scale. This can be done for a very short period of time or the adjustments can be made at half scale using half the watts.

Two and One-Half Element, Three-Phase Four-Wire Varmeters

Two and one-half element varmeters used with autotransformers are handled in the same manner as the wattmeter. The autotransformer supplies the same value of voltage as used for the wattmeter and, therefore, the adjustment can be made without using this transformer.

When two and one-half element varmeters are connected and adjusted to indicate vars without using an autotransformer, the adjustment watts as computed in the regular manner have to be multiplied by $\sqrt{3}$ since line voltage is being used rather than phase voltage as for the wattmeter. The voltage rating of the potential circuit will also be $\sqrt{3}$ times that of the corresponding wattmeter, and the wattage adjustment limits as finally computed should fall within the limits for this voltage rating.

Polarity

When adjusting wattmeters and varmeters, it is necessary to know the polarity of the current and potential circuits for upscale deflection. Figure 5 shows the instantaneous polarity for upscale deflection of the common types of Weston switchboard wattmeters and varmeters.

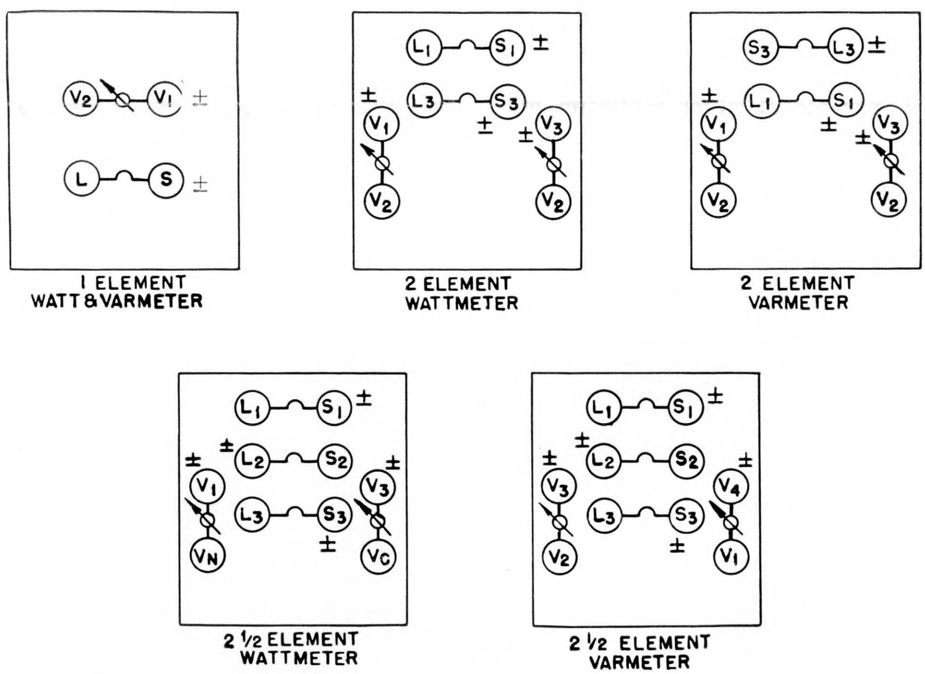


Figure 5—Polarity of Weston Wattmeters and Varmeters.

Conclusion

The main thing to consider when dealing with wattmeters is that since they indicate watts the range must be given in watts. The voltage and current ratings of a wattmeter mean nothing as far as the indication is concerned but are given for information only as to transformer secondary values and limiting circuit-carrying capacities. The range of the wattmeter is the adjustment watts as computed from the known scale range and transformer ratios. The instrument will indicate this wattage no matter how it is obtained. The voltage can be high and the current low or the voltage low and the current high and the power factor can vary from zero to unity. As long as there are watts to be measured, the wattmeter will indicate them provided it was adjusted correctly.

Also remember that the two-element wattmeter uses line voltage and line current of a three-phase three-wire system and the two and one-half element wattmeter uses the phase voltage and phase current of a three-phase four-wire system. The varmeters require the same value of voltage displaced 90 degrees. To obtain this displacement, the two-element varmeter uses the phase voltage in place of the line voltage and the adjustment watts must be reduced by their ratio (watts × .577). The two and one-half element varmeter uses line voltage instead of phase voltage and the adjustment must be increased by their ratio (watts × 1.732).

E. N.—No. 83 —*R. F. Estoppey*

THE MEASUREMENT OF TEMPERATURE FOR VOLUMETRIC DETERMINATION OF LIQUIDS IN STORAGE TANKS

General

THE effect of temperature upon certain materials may cause a physical change, such as expansion, or a change in electrical resistance. Both of these effects have been used to measure temperature—the expansion effect as exemplified by the mercury thermometer, and the change in electrical resistance makes possible the resistance thermometer.

In addition, when two different metals are joined together and heat is applied at one junction, a small voltage is developed which is dependent on the temperature difference between the hot and cold junctions. This is known as a thermocouple and, in order to use it to measure temperature, the cold junction must be kept at a uniform temperature or means of compensation provided.

The resistance thermometer is a simple device. Pure metals such as copper, nickel, silver, platinum, etc., change their resistance a specific amount for each degree of change in temperature—0.393% per degree C from 20° C for copper. The temperature coefficient of resistance of such materials remains constant within certain temperature limits for each material, provided it is properly treated. For example, copper cannot be used higher than about 300° F, nickel 600° F, and platinum 1,500° F, and still retain stability.

Thermocouples measure the temperature at a spot, that is, the junction itself. The resistance thermometer measures the temperature of a length of wire and is therefore quite flexible as to form and space. When the wire is wound in a helix and inserted in a suitable tube, it becomes a "resistance bulb."

To obtain temperature measurement, the resistance bulb is connected into a network such as a Wheatstone bridge. Voltage is applied to the bridge and the unbalance, due to resistance changes in the bulb caused by temperature, is indicated on an instrument which is calibrated in terms of temperature.

Using a standard millivoltmeter as the indicating instrument, the accuracy of the resistance thermometer depends on the accuracy with which the control voltage across the network is kept constant. The ratio meter, as exemplified by the Weston Model 918, will measure changes in resistance, and thus changes in temperature, with an accuracy that is independent of the changes in control voltage usually encountered.

Instruments

a. *For use with thermocouples:* Pyromillivoltmeters, as these instruments are called, are necessarily very sensitive. The millivolts available depend on the difference in temperature of the hot and cold junctions of the thermocouple and on the materials of which it is made, being greatest for chromel-alumel and less for platinum-platinum rhodium.

For high temperature applications, say around 2,000° F, the millivolts available would be such that any d-c millivoltmeter capable of a sensitivity of 50 millivolts full scale could be used. As the temperature for full scale deflection becomes lower, the millivolts are reduced to a point where only a very sensitive instrument such as the Weston

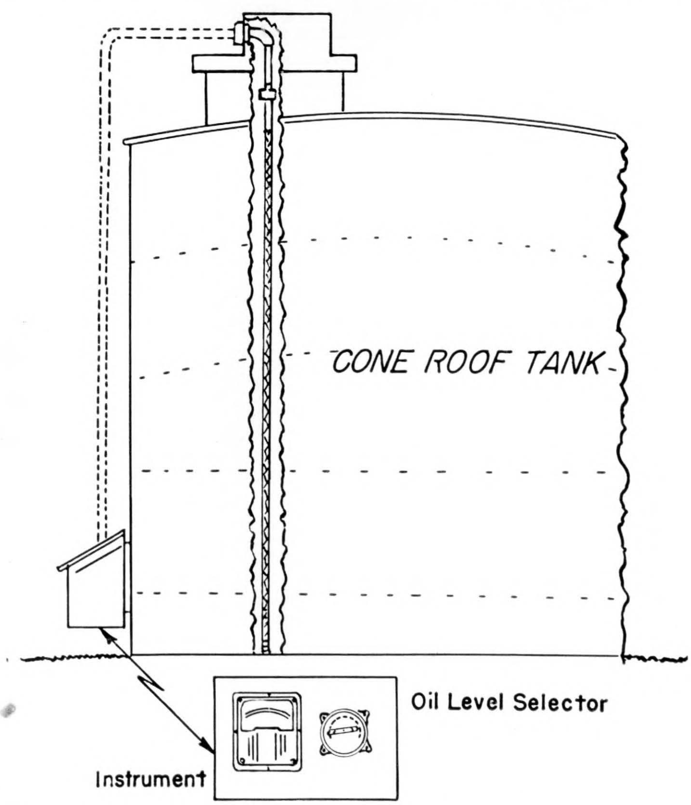


Figure 1—Installation sketch of the resistance bulb assembly in a cone roof land storage tank.

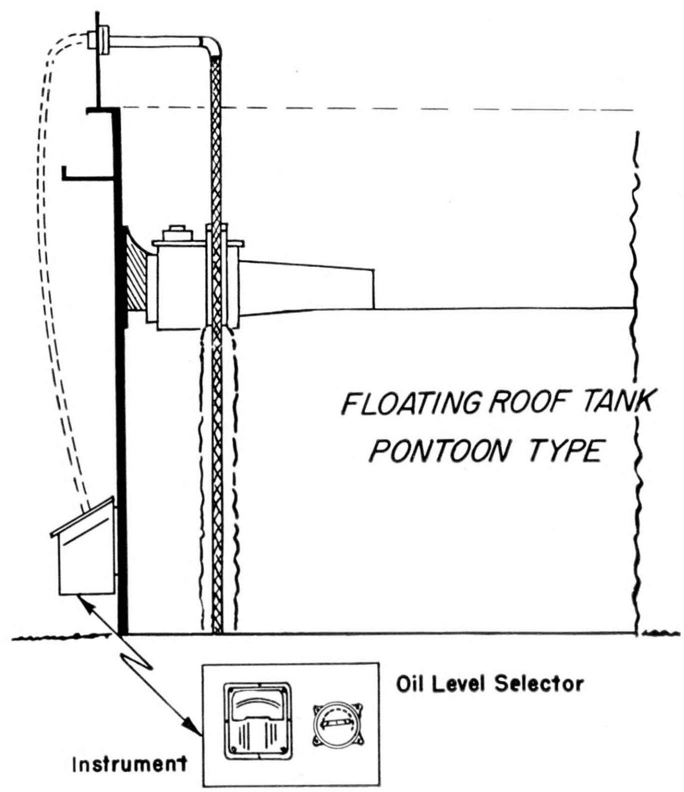
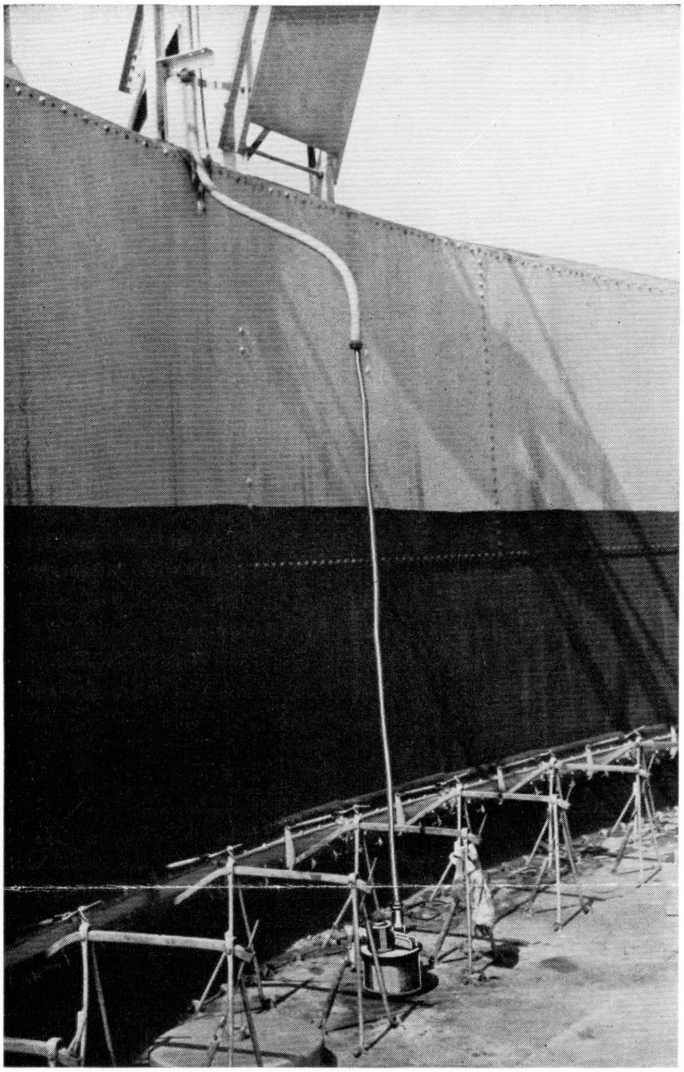
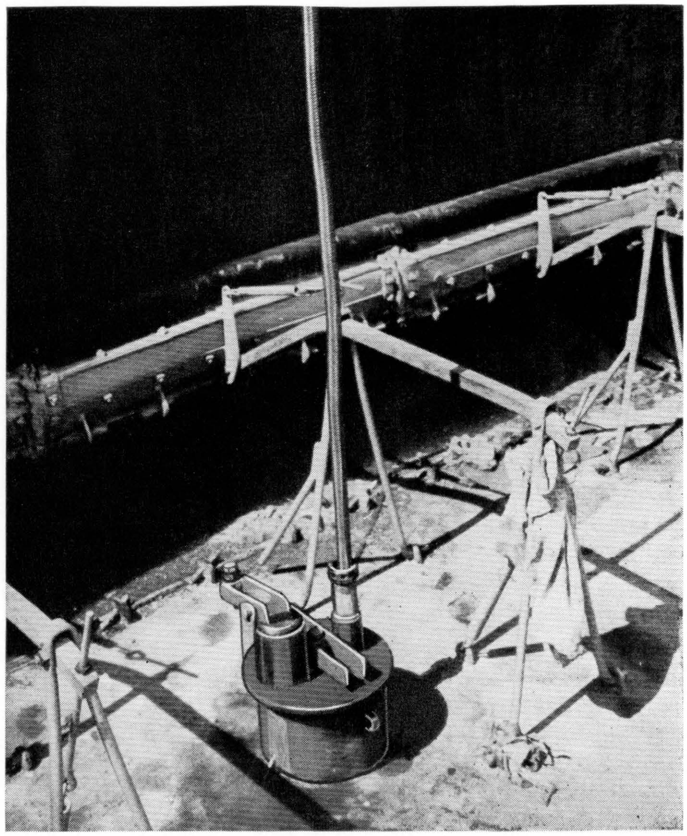


Figure 2—Installation sketch of the resistance bulb assembly in a floating roof tank.





▲ Figure 4—Modification of gaging cover on pontoon type floating roof tank to accommodate resistance bulb.

◄ Figure 3—Method of suspending resistance bulb from outer shell of pontoon type floating roof tank.

Model 319 or 622 can be used.

b. *For use with resistance bulbs:* About the only limitation that is imposed on the sensitivity requirements for an instrument used as a resistance thermometer is the current that can be circulated in the network without causing self-heating of the resistance bulb. However, by properly selecting the basic resistance of the resistance bulb, practically any Weston d-c instrument can be used. This applies, of course, only to those circuits where the bridge voltage is adjusted or otherwise held constant.

At the moment, the Weston Models 727, 728 and 828 aircraft instruments and the Model 918 Switchboard instrument are the only instruments available with the Weston ratio meter mechanism, and can therefore be used on variable voltage sources without requiring circuit adjustment.

Measurement

a. *Spot Temperatures:* All of the applications of thermometers to date have been for the measuring of spot temperatures. The thermocouple can be made smaller than a resistance bulb and consequently can measure the spot temperature of a very small object or small segment of a process. All measurement and control of processing has been done by using spot temperatures and one problem has been to locate the thermocouple or resistance bulb in the processing where it will measure the representative temperature.

When average temperatures are required, a number of spot temperatures are taken and the average temperature calculated. In order to simplify the procedure, usually at the expense of accuracy, an abbreviated method or formula is sometimes used. The accuracy of this method depends on the number and location of the spot temperatures taken and the equipment used for taking these measurements and, in order to get good accuracy, a very complete study of the problem must be made, along with the equipment and methods fitted to it.

b. *Average Temperatures:* Weston is the first to develop a resistance thermometer which will give the average temperature accurately in one reading. This reading may be continuous, for the guidance of processing, or taken as required. The problem was to develop a long resistance bulb with the resistance material evenly distributed over its entire length so that each increment of temperature along the bulb would produce its proper share of the change in resistance of the entire bulb.

These long resistance bulbs are wound with suitable wire in helical form and enclosed in a tube with suitable electrical insulation. This assembly is then enclosed in a protective housing such as a flexible metal hose, or tube, or pipe. Such resistance bulbs have already been made from three to fifty-four feet long. An installation of this type is usually found where the average temperature of a mass of material such as air, gas, or liquid is to be measured and controlled.

A single bulb can be used in tanks where the liquid level is constant or in long drying or baking ovens. An assembly of a number of bulbs of different lengths is required when the liquid level varies, as described in detail below.

Applications

There are many applications in industry where the average temperature of a product is the basis on which accounting records and operations are controlled. In the past, this information was obtained by taking a number of spot temperatures and averaging them arithmetically. The work involved in taking the readings and compiling the average is tedious and expensive and the method is subject to errors unless a large number of spot temperatures are taken.

Petroleum Industry

a. *Storage.* The volume of all bulk movements of petroleum products is recorded on the basis of the volume at 60° F. The products are not maintained at that temperature during storage so that the stored volume has to be corrected accordingly to average temperature whenever product is moved in or out of the storage tanks.

The A.P.I. (American Petroleum Institute) and A.S.T.M. (American Society for Testing Materials) have codes for determining the average temperature. When the level of oil is 15 feet or more, three readings are taken using oil cup thermometers, one three feet from the top, one at the mid-point, and one three feet from the bottom. When the level is between 10 feet and 15 feet, two temperature readings are taken, one 3 feet from the top, and one three feet from the bottom. If the oil level is less than 10 feet, one reading is taken at the mid-point.

The code also specifies a minimum waiting time of five minutes for each position of the thermometer and this time may be extended to 20 minutes for heavy oils where heat transfer is slow. The average temperature is calculated from these readings and that is the temperature used for calculating the volume at 60° F. The level is obtained with a plumb bob and steel tape and the constants of each tank are known.

The heavier oils are stored in tanks equipped with some method of heating the product, such as steam coils in the tank, or by circulating through a heat exchanger. This is necessary so that the viscosity is lowered enough to pump it. The temperature of a product varies from about 65° F at the bottom, below the heating coils, to a mid-point temperature which may be as high as 105° F, and the upper part is cooler in winter, due to the effects of outside temperature.

Under these conditions, the average temperatures taken according to the A.P.I. and A.S.T.M. codes are not accurate. In heavy fuel oils at the lower temperatures, tests have shown that the oil cup thermometer requires 55 minutes to reach an accurate reading.

Heavy oils are normally stored in cone roof tanks. Gasoline and the lighter products are stored in pressurized tanks, such as floating roof tanks, to reduce losses due to evaporation. The temperature of the product depends upon the outside air temperature, and is colder in winter than in summer. Since the heat transfer through the lighter material is better, temperature readings taken according to A.P.I. and A.S.T.M. codes are more accurate than in the case of the heavy oils. However, since the product sells at a higher price, a small error on gasoline storage may represent the same dollars as the larger error on the heavier oils.

Field tests have proved that the errors, when using oil cup thermometers according to code, may be as great as 10° F on heated products. Since these measurements are taken from the top of the tank, under adverse weather conditions, it is doubtful if a gager will wait for even five minutes for each of three readings.

The percentage loss per degree F error may be low, but the tanks hold thousands of barrels so that the dollars accumulate quite rapidly. On one tank, where calculations were made, a 0.2% error on the total quantity moved in a year amounted to about $5,000.00.

Averaging Resistance Thermometer for Land Storage Tanks

A resistance bulb assembly for land storage tanks consists of a number of resistance units varying in length depending on the height of the tank and mounted in a single flexible tubing. For example, a cone roof tank, with 36 feet of oil in it when full, would use a bulb consisting of 9 units. The shortest unit would be 4 feet long and each successive unit 4 feet longer, the longest being 36 feet. Each resistance unit regardless of its length has a resistance of 100 ohms at 25° C. The outer protective tubing of the bulbs is a ½-inch pipe size flexible bronze hose which is plugged at the bottom and terminates at the top with a short length of pipe, an elbow, and a threaded section of pipe with two flanges. The side of the gaging hatch riser is drilled and the assembly suspended in the tank. (See Figure 1.)

There are two methods of installing this resistance bulb assembly on a floating roof tank:

a. The resistance bulbs are assembled with all resistance units starting at the top. The assembly in the flexible hose is fastened to the roof and, as the roof goes down, the hose coils up at the bottom of the tank.

This method requires either putting the tanks out of service or flooding the area with CO_2 during the drilling operation to prevent an explosion. Both of these safety measures are expensive.

b. On installations that have been made, the assembly in the metal hose was prepared in the usual manner with all resistance units starting at the bottom. This assembly was suspended from an arm fastened to the top of the tank shell so that it would pass through the gaging hatch. The gaging hatch cover was removed, taken to the machine shop, and short lengths of 3-inch and 1½-inch pipe were welded to the cover. The 1½-inch pipe was equipped with a bakelite bushing and the resistance bulb assembly passed through this pipe and was a loose fit. As the roof went up and down, the 1½-inch pipe slid up and down on the flexible hose. (See Figures 2, 3, 4.)

Weston supplies the complete resistance bulb assembly in the bronze flexible hose. Coded flexible leads are brought out, one from each resistance unit, a common, and the third lead to neutralize lead resistance. The customer mounts a connection box and runs leads from there to the meter and selector switch location.

On some installations, the meter and selector switch, together with 6 volts of dry cells and switch, are mounted in a box at the foot of the stairs going up to the tank. On others, the meter box is mounted at the top of the tank, since the gager has to climb the tanks to get a level reading.

Batteries have been used as a power source to avoid the necessity of running power lines into the tank farm. The batteries have shelf life and the energy in the resistance bulb arm of the bridge circuit is so low that the safety engineers at the refineries have approved it.

Bronze flexible hose is used to house the resistance bulb assembly because the housing must be made of non-arcing metal so as to avoid any sparking.

The Weston Model 918 instrument is calibrated in 1° F divisions and a scale of 60-180° F is recommended for heated products and a scale of 0-120° F for unheated products.

The selector switch is captioned "Oil Level Selector" and each point is marked with the range of oil level covered by the resistance unit connected to that point. For example, with the resistance units progressing in length by 4 feet, the point on the dial switch to which the 8-foot unit was connected would be marked 8 to 12 feet. At the "0" position, there is a fixed resistance of zero temperature coefficient which gives a reading of 70° F on the scale of the meter. This provides a quick check on calibration.

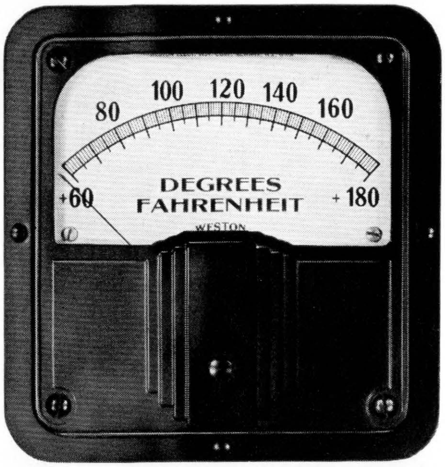


Figure 5—The Weston Model 918 Electrical Resistance Thermometer.

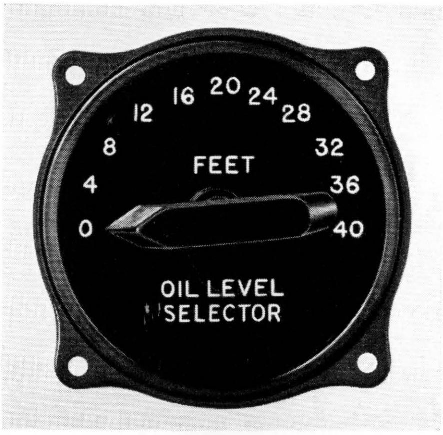


Figure 6—The Oil Level Selector Switch used with the Model 918.

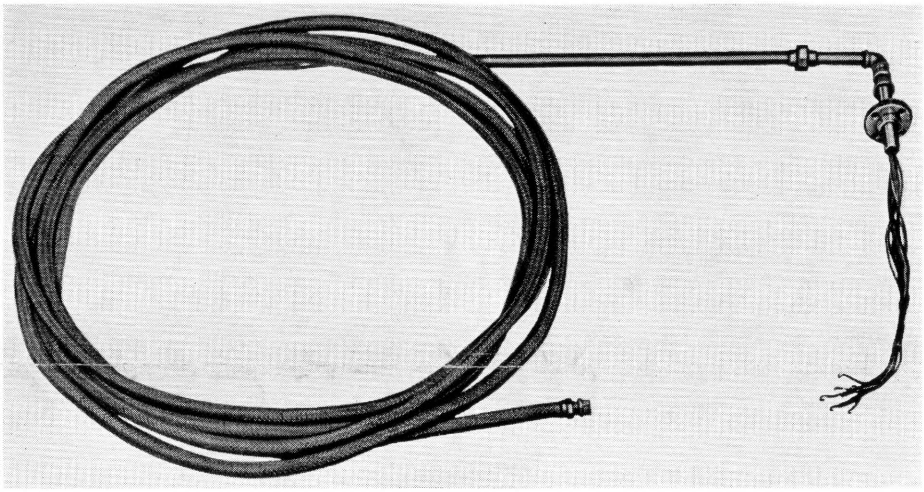


Figure 7—The bronze flexible hose shown here is used to house the resistance bulb assembly.

It is recommended that Number 14 wire be used for all connections between the resistance bulb assembly and the dial switch and meter, provided the distance between them is not greater than 500 feet. However, smaller wire may be used for long runs provided the instrument is calibrated for this condition.

Other Industries

The petroleum industry is the only industry that has been explored in detail. However, there are other industries that store liquid products in volume and all liquids change their volume with temperature.

a. *Chemical Industry:* Manufacturers of industrial chemicals have large storage tanks and are interested in temperatures. In some cases they sell in tank car lots and weigh the product. However, they check the storage tanks and should be interested in average temperature.

b. *Food Industry:* Manufacturers of syrups store their product in large tanks and temperature is an important factor.

Control

In many instances such as in long drying ovens, blending operations, and the like, more desirable controls can be obtained using average temperature as a basis than by trying to locate spot temperature devices at a place which gives the effect of average temperatures.

Averaging resistance bulbs can be used with sensitive relays or with Tag Celectray controllers. The Tag Celectray controller can be made in the ratio type to be independent of control voltage.

E. N.—No. 82 —*R. T. Pierce*

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