AUTOMOTIVE
Maintenance and Trouble Shooting

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I figured after last month's column, your head is aching from the complicated mathematical formulas. Let's move on to something a little more 'hands-on'. This is a rather long excerpt from a later book, 1954. The contents on how dash-board gauges work and how to troubleshoot and repair them are applicable to both older cars and many later ones, too. This month we will cover the first four topics listed below. The balance will be in the April issue.

INSTRUMENTS

I. Electrical Instruments
II. Non-electrical Instruments
III. Ammeters
IV. Voltmeters (Charge Indicator)

V. Fuel Level Gauge .
VI. Oil Pressure Gauge
VII. Temperature Gauge
VIII. Mechanical Speedometers
IX. Electrical Speedometers and Tachometers

See these topics in the April issue.

Trouble shooting procedures for the many types of instruments used on automotive vehicles must be varied to suit the basic design of the instrument. Obviously, different methods are used in testing electrical instruments than are used to test non-electrical instruments. Even within these two broad classifications, a variety of basically different types are used, all of which must be understood. In the case of electrical instruments, the relationship of the instrument circuit to other circuits of the vehicle must be appreciated.

In general, the instruments with which automotive vehicles are equipped are not to be considered as accurate measuring devices but rather merely as "indicators" that are entirely adequate for their intended purpose.

I. ELECTRICAL INSTRUMENTS

To understand an electrical instrument, it is necessary to know the entire circuit of the particular instrument being considered. Moreover, several basically different types of electrical instruments are commonly used to do the same job in different makes of vehicles. In this section these different types of instruments are explained and their location in the electrical system of the vehicle is described.

The generator-battery circuit represents the source of current for all of the electrical requirements of the vehicle, and at least a part of this circuit is a part of each of the other circuits as well. Electrical instrument circuits, like all other circuits, are energized from the battery-generator circuit. An understanding of how they operate or why they fail to operate must be based on an appreciation not only of how the instrument works but its relationship to these other circuits as well. Electrical instruments only are discussed in this section. Non-electrical instruments are discussed in Section II of this chapter.

Most instruments are connected into the ignition circuit. The instrument circuits are connected to the cold side of the ignition switch so that when the ignition switch is turned off, the

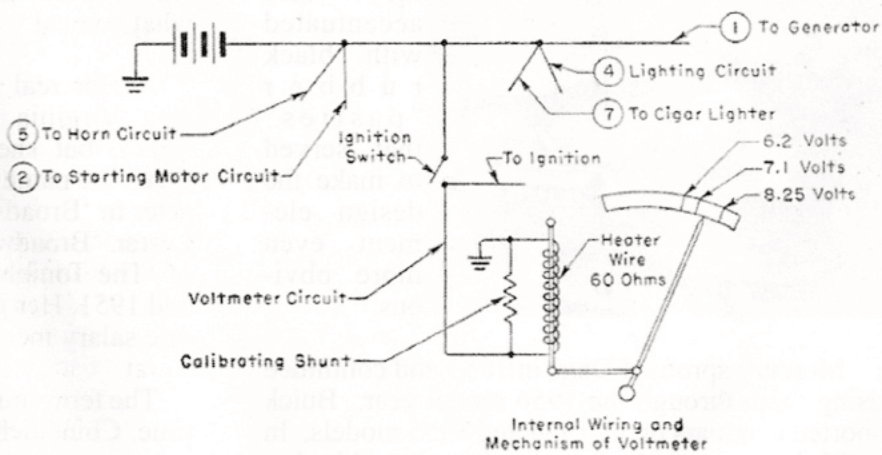

Fig. 1. Charge Indicator (Voltmeter) Circuit

instruments are likewise off. An exception to this is the ammeter, which is in series in the generator to battery circuit.

a. **Ammeters**. Three different types of ammeters are used in automotive vehicles.

The expensive moving coil type meter is used only on military or other high-priced vehicles. These meters generally have an opening at the bottom of the dial face through which you can see the coil.

Some automotive ammeters have two terminals. If the wires to these terminals are transposed, the instrument will show charge when the battery is discharging and discharge when it is charging. Some automotive ammeters have no terminals, with the generator-to-battery wire merely passing through a loop on the back of the instrument.

b. **Voltmeters**. For several years, Ford Motor Company products used a voltmeter rather than an ammeter. In this instance, this instrument, like most electrical instruments, is connected from the cold side of the ignition switch to ground as shown in Fig. 1. This is a heater-wire type voltmeter and its slow reaction does not permit its use for testing purposes.

The heater-wire type voltmeter is like a thermal circuit breaker, except that as the bimetal heats, instead of breaking a circuit it actuates the instrument hand or pointer through a mechanical linkage as shown in Fig. 1. In drawing this unit in a circuit drawing, it can be shown the same as the thermal circuit breaker except for the omission of the contact points.

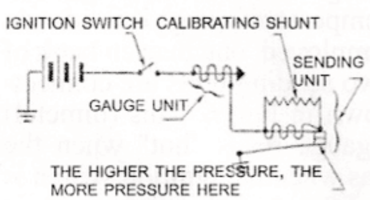

FIG. 2 KING-SEELEY FUEL GAUGE CIRCUIT

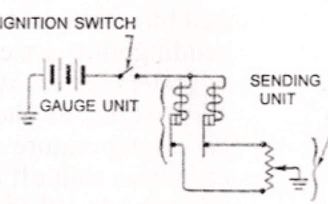

FIG 3. DOUBLE CIRCUIT, BIMETAL TYPE, FUEL LEVEL GAUGE

c. **Fuel Level, Temperature, and Oil Pressure Gauges**. Three basic differences in design are employed in fuel level, temperature, and oil pressure gauges.

(1) SINGLE-CIRCUIT BIMETAL. A variation of the heater-wire type voltmeter is used for several other kinds of instruments. Fig. 2 shows a King-Seeley fuel level gauge that is this type of instrument. In this circuit, the instrument is shown the same as a thermal circuit breaker except that instead of contacts that break a circuit, the end of the line representing the bimetal carries an arrowhead indicating a pointer.

All electrical fuel level, temperature, and oil pressure gauges mounted on the instrument panel have a sending unit which is also a part of the circuit. In the King-Seeley type shown in Fig. 2, the sending unit also is constructed like a thermal circuit breaker. The bimetal around which the heater wire is wrapped carries a contact point. Another contact point connected to ground presses against the contact point on the bimetal. This pressure varies according to the level of the fuel in the tank. The more the pressure, the more current required to break the contact and the higher the reading on the gauge unit. Once the contact is broken, the bimetal cools and contact is re-established almost immediately.

A test ammeter installed in series in this circuit will show the current flow to be intermittent. The slow reaction characteristics of the gauge unit, however, result in a steady, continuous reading. This reading reflects the average current and indicates the level of the fuel in the tank.

The shunt (non-inductive resistance) shown in the sending unit in Fig. 2 is merely a by-pass installed at the time of the assembly of the instrument in order to compensate for the normal variations occurring during manufacture.

(2) DOUBLE - CIRCUIT BIMETAL. Another type of electric fuel level-gauge circuit is shown in Fig. 3. In this arrangement the sending unit is a rheostat actuated by a float in the fuel. When the fuel tank is empty, the resistance through the one heater wire is low and the resistance through the other is high, since the whole of the rheostat resistance has been added to it. At other levels of fuel, the ratio of resistance of the one leg of the circuit to the other varies according to how full the fuel tank is.

(3) BALANCED COIL TYPE. Fig. 4 illustrates a balanced coil type fuel gauge. In this circuit a rheostat is also used in the sending unit.

However, in this case only a single wire runs from the sending (tank) unit to the gauge.

Fig. 5 shows all of the elements of the circuit in simplified form. It should be noted that the current from the ignition circuit runs to the gauge unit where it divides between the two inductive resistances as shown. One of these coils is grounded in the gauge unit, whereas the ground for the second coil is through the rheostat in the sending unit. The level of the fuel in the tank determines the amount of the resistance from the rheostat that is added to this second leg of the circuit. The relationship of the magnetic pull of the one coil to the other determines the position of the gauge pointer.

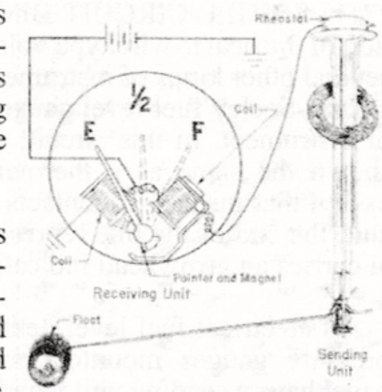

Fig. 4 Balanced Coil Type Gauge
(Courtesy AC Spark Plug Div. - General Motors)

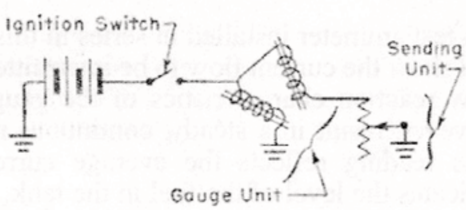

Fig. 5. Balanced Coil Type Fuel Gauge Circuit with Single Sending Unit

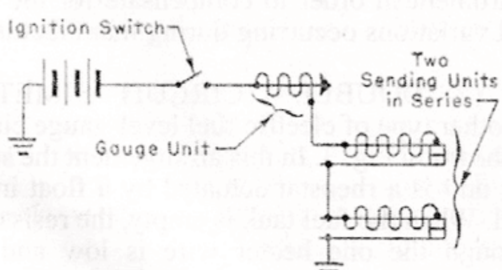

Fig. 6. Bimetal Type Temperature Gauge Circuit with Two Sending Units

(4) OIL PRESSURE GAUGES. Two of the three types of gauge units just described under the discussion of electric fuel gauge circuits are also used as oil pressure gauges. These two types are the King-Seeley single-circuit bimetal type (Fig. 2), and the balanced coil type (Fig. 5). In each of these types, of course, the sending unit differs from the fuel gauge circuit sending unit. Instead of a float actuated mechanism, the oil pressure gauge sending unit is actuated by oil pressure. In both instances a diaphragm is distorted in proportion to the pressure.

In the bimetal type, this pressure increases the contact point pressure just as a high fuel level does in the fuel level gauge. Electrically, Fig. 2 applies to this type of oil pressure gauge as well as to the fuel level gauge.

In the balanced coil type, the distortion of the diaphragm changes the resistance of the sending unit. Electrically, Fig. 5 applies to this oil pressure gauge as well as to the fuel level gauge.

(5) TEMPERATURE GAUGE. As is true of the oil pressure gauge, two of the three types of gauge units described under the discussion of electric fuel gauge circuits are also used as engine temperature gauges. The sending unit for these two types of gauges differs mechanically from the sending unit in the corresponding fuel gauge circuit. In both of these temperature gauge circuits, the sending unit is actuated by temperature.

Electrically, Fig. 2 applies to the single-circuit bimetal type temperature gauge circuit as well as to the fuel gauge circuit. Likewise, Fig. 5 applies electrically to the balanced coil type temperature gauge circuit as well as to the corresponding fuel gauge circuit.

In some V type engines where the single-circuit bimetal type temperature gauge is used, two sending units are employed, one in each bank of cylinders. These two sending units are connected in series as shown in Fig. 6. This (bimetal) type temperature gauge reads "hot" when the current is shut off as when the ignition switch is off or when either of the sending unit contacts is open. By this arrangement, in the event one bank of cylinders is running hotter than the other, the temperature shown on the gauge unit indicates the temperature of the hotter of the two banks of cylinders.

d. Electric Speedometers. Electric speedometers, so far as trouble shooting is concerned, are just like mechanical speedometers except that the sending unit generates an electric current which is carried to the speedometer head through wires. Since this circuit generates its own current, the circuit is entirely independent of the battery-generator circuit.

Electric speedometers (or tachometers) generally are used on vehicles only where it would be impractical to connect the speedometer drive gear directly to the head through a mechanical drive cable. A bus, in which the engine is mounted at the rear, is a good example of the kind of vehicle that uses an electric speedometer.

II. NONELECTRICAL INSTRUMENTS

In addition to the electrical instruments discussed in the preceding section, most vehicles use some non-electrical or mechanical instruments. The various non-electrical instruments used in automotive vehicles measure pressure, temperature, and speed. Electrical instruments have mechanical parts that convert a mechanical pressure or a temperature to an electrical value that is read in terms of pressure or temperature at the receiving unit.

In general, the non-electrical instruments are completely non-electric.

An exception to this is the mechanical speedometer that, while mechanical in construction, uses a magnetic field in the head unit to reflect the speed. Mechanical speedometers are mechanical in the sense that they are driven mechanically. In the speedometer head a permanent magnet rotates with the drive cable. It is this rotating magnet that causes the speedometer pointer to deflect in proportion to speed. Thus, we see that the mechanical speedometer is actually magnetic. Magnetism, of course, is closely associated with electricity.

Pressures can be measured with a bourdon tube, a diaphragm, or U tube. All of these methods are or at one time were used as dash instruments in automotive vehicles. Each of these is briefly discussed here.

Bourdon tube gauges are used primarily to indicate engine oil pressure. The instrument is connected directly to an engine oil line through tubing.

A diaphragm exposed to pressure on one side and having mechanism to resist movement on the other side can be used to measure pressures directly or as a part of a sending unit in electrical instrument circuits.

U tubes have been used in fuel level gauges, oil level gauges, and temperature gauges. The range of the instrument is determined by the specific gravity (weight) of the liquid used in the U tube.

Mechanical temperature gauges are known as the vapor pressure type. In this type of instrument, temperature is indicated by means of pressure. The troubles normally experienced with this instrument are discussed elsewhere. The principles of operation that apply to pressure measurements are presented in the following paragraphs.

a. Pressure Measurements. Pressures are measured in pounds per square inch (psi). A pressure of one hundred pounds per square inch means a total pressure of one hundred multiplied by the number of square inches on which it is working. Thus, this one hundred pound pressure working against a diaphragm or piston of five square inches in area would exert a lifting force of five hundred pounds. Or, if working against an area of one-half square inch, it would exert a lifting force of fifty pounds.

The atmosphere around the earth has a pressure of approximately 14.7 psi at sea level. Pressures less than atmospheric are referred to as vacuums. The value of the vacuum is the difference between the atmospheric pressure and the pressure within the vessel under vacuum.

The unit of measurement for the vacuum is inches of mercury. This unit of measurement is based on the ability of the pressure differential to lift mercury in a tube. The three common forms of pressure gauges are U tubes, bourdon tubes, and diaphragms.

(1) U TUBES. If a tube formed into a U shape as shown in Fig. 7 is partially filled with a liquid, it can be used to measure pressures. These pressures can be expressed in pounds per square inch, inches of mercury, or inches of water. When two different pressures are applied to the two surfaces of the liquid in the U tube as shown in Fig. 7, the greater pressure will push

down on the one surface of the liquid and cause the liquid in the other leg of the U to rise. The height of the liquid in the low-pressure tube indicates the pressure differential.

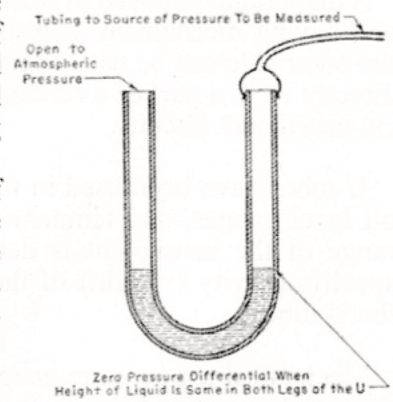

Fig. 7. U Tube Used for Pressure Measurements

One leg of the tube generally is open to atmospheric pressure and the other leg is connected through tubing to the source of the pressure to be measured. If this tube is connected to a source of vacuum, atmospheric pressure pressing down on the surface of the liquid on the other side will cause it to rise in the low-pressure leg. The amount the liquid rises indicates the pressure differential.

Where pressures above atmospheric pressure are to be determined, the pressure to be measured is applied to the surface of the liquid in the one leg of the U tube. This presses the liquid downward and causes it to rise in the other leg. This movement continues until the weight of liquid lifted is equal to the pressure applied.

Such instruments are referred to as manometers. Manometers are widely used on distributor test fixtures where strict accuracy is required. The weight of the liquid used in the U tube determines the graduations. One pound pressure will lift a column of mercury approximately two inches. Since mercury has a specific gravity of 13.546 (at 68° F) and water has a specific gravity of 1.000, this same pressure (one pound) will lift a column of water approximately twenty-seven inches. Other liquids heavier than water but lighter than mercury are also commonly used.

Inexpensive U tubes have been used as automotive vehicle instrument panel equipment for indicating engine temperatures, fuel level, and other purposes.

(2) BOURDON TUBE. A bourdon tube gauge consists essentially of a curved, slightly elastic tube, oval in section. One end of this tube is open to the pressure to be measured. The other end of the tube is closed and is connected to a movable hand or pointer that indicates the pressure on a dial. See Fig. 8.

An increase in pressure in the tube causes the curve to straighten in proportion to the pressure. Bourdon tube gauges are used to measure either liquid or gas pressures. The instrument generally is connected directly to the source of pressure through tubing.

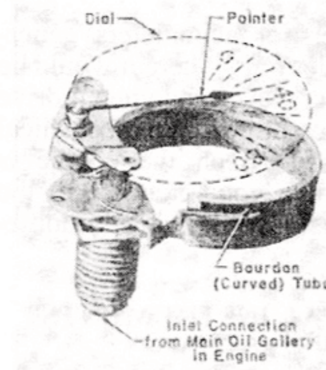

Fig. 8. Typical Pressure Expansion Type Oil Pressure Gauge
(Courtesy Stewart-Warner Corporation)

In maintenance work, bourdon tube gauges are commonly used to measure intake manifold vacuum (range 0 to 30 ins. of mercury), fuel pump vacuums (range 0 to 30 ins. of mercury), fuel pump pressures (range 0 to 10 lbs.), engine compression (range 0 to 200 lbs.), engine oil pressure (range 0 to 100 lbs.).

Bourdon tube gauges are used also to measure the hydraulic pressures used to actuate automatic transmission gear shifts and the hydraulic pressures in tractor hydraulic systems used to lift or control the implements.

(3) DIAPHRAGM. A diaphragm exposed to pressure on one side and having a mechanism to resist movement on the other, can be used to measure pressures directly. This type of pressure gauge has been used on some distributor test benches. The more common use of the diaphragm, however, is as a part of a sending unit in electrical instrument circuits.

III. AMMETERS

The only troubles encountered with an ammeter are that it fails to register, reads incorrectly, or reads backward. Typical ammeter circuit diagrams are shown in Fig. 9. The points where wiring connections are made are shown by dots. In some vehicles, additional connections may be used depending on the location of the ammeter or the relation of the ammeter circuit to other electrical circuits of the vehicle.

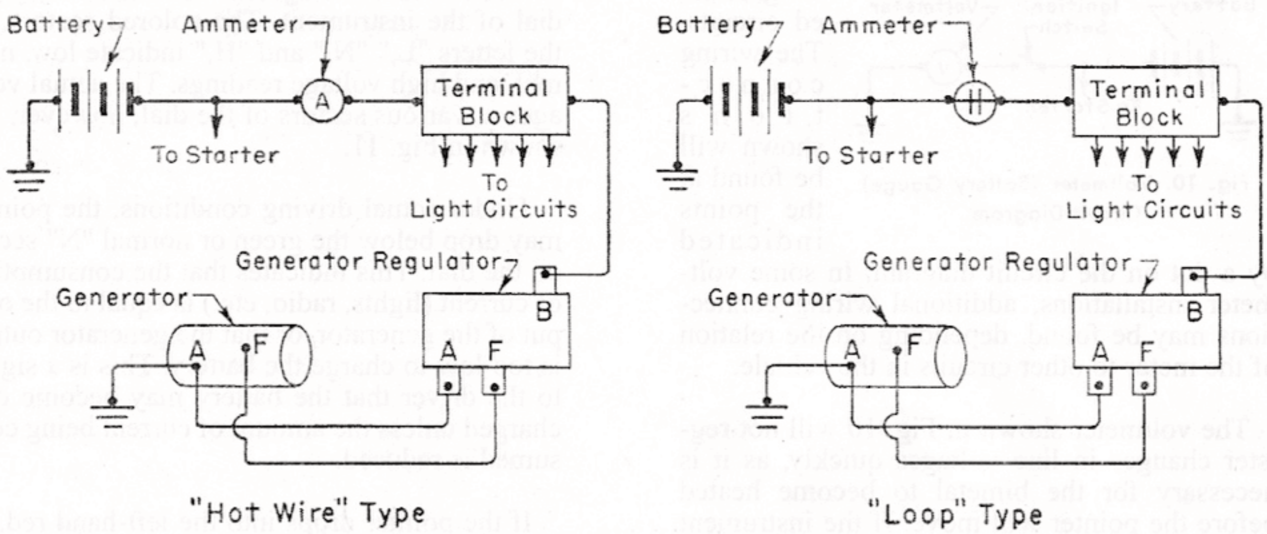

Fig. 9. Ammeter Circuit Diagrams

a. Fails to Register. If the ammeter fails to register, the following trouble shooting procedure will merely confirm this fact: turn off all lights and electrical accessories, start the engine and run it at a speed equivalent to a car speed of about 20 mph. If the ammeter pointer fails to indicate "charge" for at least the time required to restore the current used in starting, either the generating system or the ammeter is at fault.

Stop the engine and turn on the headlights. The pointer should move to the discharge side of the dial. If the pointer will not indicate on either side of the dial, the instrument should be replaced.

If the ammeter pointer or dial is distorted, or if the instrument itself is faulty, it is not practical to attempt repairs. A new instrument should be installed.

b. Reads Incorrectly. If it is reported or suspected that the ammeter reads incorrectly, connect an accurate test ammeter in series with the ammeter on the vehicle and test to compare the readings of the two instruments.

NOTE: *Most ammeters used in passenger or commercial vehicles only indicate the flow of current. They seldom show accurately how much current is flowing. Consequently, the dials at these ammeters are not calibrated to show actual amperes; on some instruments only the words "charge" or "discharge" are used.*

c. Reads Backward. If the ammeter reads backward, it is connected wrong. If the wires connected to the binding posts on the back of the 'hot wire" type ammeter are reversed, the ammeter indication will be reversed. Likewise, if the wire running through the loop of a "loop" type ammeter passes through the loop in the wrong direction, the ammeter will read backward. Disconnect one end of this wire and remove it from the loop: Thread the wire through the loop in the opposite direction to reverse the readings.

IV. VOLTMETER (CHARGE INDICATOR)

The voltmeter was used some years ago on Ford passenger cars in place of an ammeter. On some types of military vehicles, particularly those with radio sending and receiving equipment, both an ammeter and a voltmeter are used. Two troubles can occur in the operation of a voltmeter: it may fail to register or it may register incorrectly.

a. Fails to Register. Turn on the ignition switch. The pointer should move to a position indicating the voltage available at the battery. If the pointer fails to move, it can be assumed that the battery is completely discharged, or that the instrument itself or the wiring circuit is at fault.

The circuit diagram of a typical voltmeter installation is shown in Figs. 1 and 10. Before condemning the instrument itself, test for open

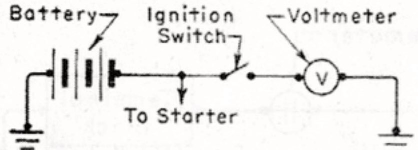

Fig. 10. Voltmeter (Battery Gauge) Circuit Diagram

or grounded circuits. The wiring connections shown will be found at the points indicated by a dot on the circuit diagram. In some voltmeter installations, additional wiring connections may be found, depending on the relation of the meter to other circuits in the vehicle.

The voltmeter shown in Fig. 10 will not register changes in line voltages quickly, as it is necessary for the bimetal to become heated before the pointer will move. If the instrument is found to be at fault, a new one should be installed, as it is not practical to attempt repairs.

b. Registers Incorrectly. To test the accuracy of the voltmeter, connect an accurately calibrated test voltmeter from the battery side of the voltmeter to ground (Fig. 10). Turn the ignition switch on and compare the readings of the two instruments.

The dials of some typical voltmeters are shown in Fig. 11. The actual voltages are not shown on the dial of the instrument. The colored sectors, or the letters "L," "N," and "H," indicate low, normal, and high voltage readings. The actual voltages at various sectors of the dial, however, are shown in Fig. 11.

Under actual driving conditions, the pointer may drop below the green or normal "N" sector on the dial. This indicates that the consumption of current (lights, radio, etc.) is equal to the output of the generator, or that the generator output is too low to charge the battery. This is a signal to the driver that the battery may become discharged unless the amount of current being consumed is reduced.

If the pointer drops into the left-hand red, or low "L" sector, this is a warning to the driver that the battery is being discharged.

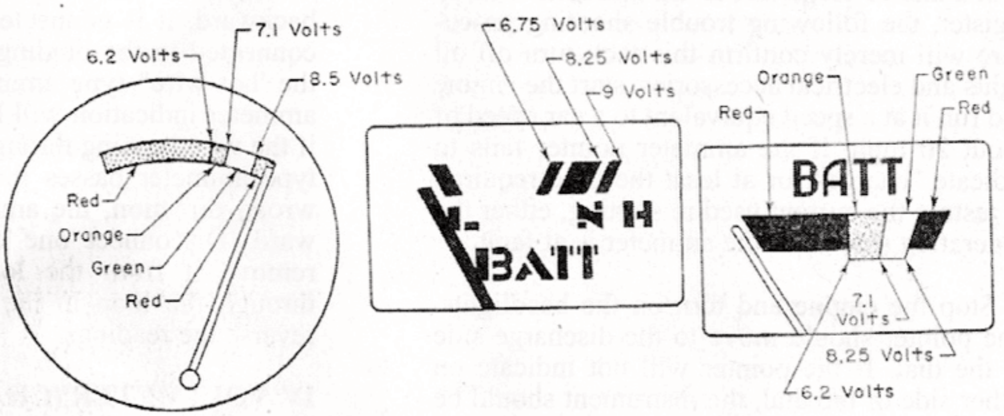

Fig. 11. Typical Voltmeter (Battery Gauge) Dials

(Courtesy Ford Motor Company)

S.K.

This series will continue next month covering those gauges not discussed in the above article: Fuel Level Gauge, Oil Pressure Gauge, Temperature Gauge, Mechanical Speedometers, Electrical Speedometers and Tachometers will be featured in the April 2012 issue of *Skinned Knuckles*.

Within the next month or two many of you will be returning to your homes in the North. Be sure that you notify us ***in writing***, by e-mail or letter, of the date of change, the old address and the new address. We do not keep records of previous addresses. A change of address must be submitted 30 days in advance each time you move. We are not responsible for lost or missed issues because you moved.

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