CHAPTER 14

TEST METHODS

14-1. Test evaluation.

The tests listed in this chapter are most commonly performed to determine the condition of low voltage equipment. If a testing program is to provide meaningful information, all tests must be conducted in a proper manner. All conditions which would affect the evaluation of these tests must be considered with any pertinent factors recorded. The test operator must be thoroughly familiar with the test equip ment used and should also be able to detect any equipment abnormalities or questionable data during the performance of the test. To provide optimum benefits, all testing data and maintenance actions must be recorded. The data obtained in these tests provide information which:

a. Determines whether any corrective maintenance or replacement is necessary or desired.

b. Ascertains the ability of the element to continue to perform its design function adequately.

c. Charts the gradual deterioration of the equipment over its service life.

14-2. Insulation testing.

Insulated electric wire is usually made of copper or aluminum (which is known to be a good conductor of the electric current) conductor with appropriate insulation for the rated voltage. The insulation must be just the opposite from a conduction it should resist current and keep the current in its path along the conductor. The purpose of insulation around a conductor is much like that of a pipe carrying water (fig 14-1). Pressure on water from a pump causes flow along the pipe. If the pipe were to "spring a leak", water would spout out; you would waste water and lose some water pressure. With electricity, "voltage" is like the pump pressure causing electricity to flow along the copper wire. As in a water pipe, there is some resistance to flow, but it is much less along the wire than it is through the insulation. Insulation, with a very high resistance, lets very little current through it. As a result, the current follows a "path of least resistance" along the conductor. The failure of an insulation system is the most common cause of problems in electrical equipment. Insulation is subject to many effects which can cause it to fail; such as, mechanical damage, vibration, excessive heat, cold, dirt, oil, corrosive vapors, moisture from processes, or just the humidity on a muggy day. As pin holes or cracks develop, moisture and foreign matter penetrate the surfaces of the insulation, providing a low resistance path for leakage current. Sometimes the drop in insulation resistance is sudden, as when equipment is flooded. Usually, however, it drops gradually, giving plenty of warning, if checked periodically. Such checks permit planned reconditioning before service failure. If there are no checks, a motor with poor insulation, for example, may not only be dangerous to touch when voltage is applied, but also be subject to bum out. Current through and along insulation is made up of three components (fig 14-2): capacitance charging current; absorption current; and conduction or leakage current. The total current is the sum of the three components and it is this current in terms of megohms at a particular voltage that can be measured directly by a megohmmeter. Note that the charging current disappears relatively rapidly, as the equipment under test becomes "charged". Larger units with more capacitance will take longer to be charged. This current also is the stored energy initially discharged after your test, by short-circuiting and grounding the insulation. You can see further that the absorption current decreases at a relatively slow rate, depending upon the exact nature of the insulation. This stored energy, too, must be released at the end of a test, and requires a longer time than the capacitance charging current-about four times as long as the voltage was applied. With good insulation, the conduction or leakage current should build up to a steady value that is constant for the applied voltage. Any increase of leakage current with time is a warning of trouble. With a background now of how time affects the meaning of instrument readings, let's consider two common test methods: (1) short-time of spot reading and (2) time-resistance tests.

a. Short-tin or spot-reading test. In this method, connect the megohmmeter (para 13-4) across the insulation to be tested and operate it for a short, specific timed period (60 seconds usually is recommended). Commonly used DC test voltages for routine maintenance are as follows:

Equipment AC Rating	*DC Test Voltage*
up to 100 volts	100 and 250 Volts
440 to 550 volts	500 and 1,000 Volts

Bear in mind also that temperature and humidity, as well as condition of your insulation affect your reading. Your very first "spot reading" on equipment, with no prior test, can be only a rough guide

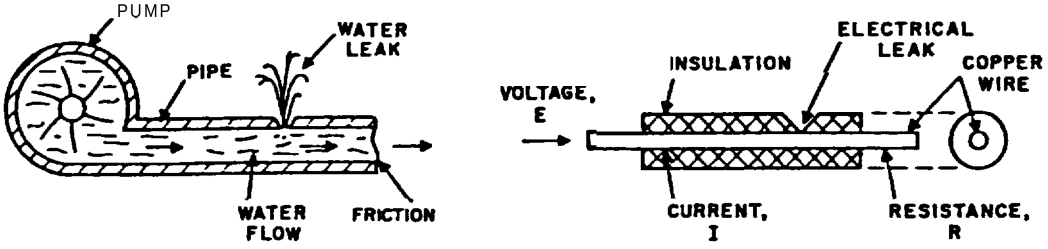

Figure 14-1. Comparison of water flow with electric current.

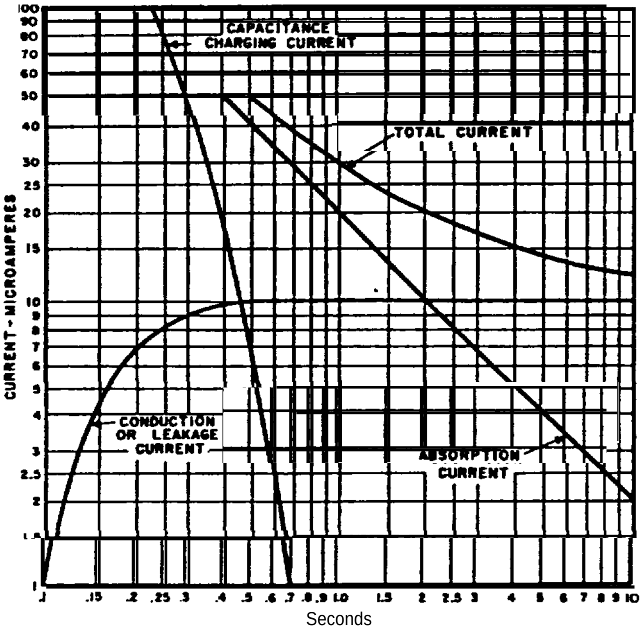

Figure 14-2. Curves showing components of measured current during insulation testing.

as to how "good" or "bad" is the insulation. By taking readings periodically and recording them, you have a better basis of judging the actual insulation condition. Any persistent downward trend is usually fair warning of trouble ahead, even though the readings may be higher than the suggested minimum safe values. Equally true, as long as your periodic readings are consistent, they may be O.K., even though lower than the recommended minimum values. You should make these periodic tests in the same way each time, with the same test connections and with the same test voltage applied for the same length of time. In table 14-1 are some general observations about how you can interpret periodic insulation resistance tests, and what you should do with the result.

b. Time-resistance method. This method is fairly independent of temperature and often can give you conclusive information without records of past tests. It is based on the absorption effect of good insulation compared to that of moist or contaminated insulation. You simply take successive readings at specific times and note the differences in readings. Tests by this method are sometimes referred to as absorption tests (fig 14-3). Test voltages applied are the same as those listed for the spot-reading test. Note that good insulation shows a continual increase in resistance over a period of time. If the insulation contains much moisture or contaminants, the absorption effect is masked by a high leakage current which stays at a fairly constant value-keeping the resistance reading low. The time-resistance test is of value also because it is independent of equipment size. The increase in resistance for clean and dry insulation occurs in the same manner whether a motor is large or small. You can, therefore, compare several motors and establish standards for new ones, regardless of their horsepower ratings. The ratio of two time-resistance readings is called a Dielectric Absorption Ratio. It is useful in recording information about insulation. If the ratio is a ten minute reading divided by a one minute reading, the value is called the Polarization Index. Table 14-2 gives values of the ratios and corresponding relative conditions of the insulation that they indicate.

Table 14-1. Interpreting insulation resistance test results.

CONDITION	WHAT TO DO
1. Fair to high values and well-maintained.	No cause for concern.
2. Fair to high values, but showing a constant tendency towards lower values.	Locate and remedy the cause and check the downward trend
3. Low but well-maintained.	Condition is probably all right, but cause of low values should be checked.
4. So low as to be unsafe.	Clean, dry-out, or otherwise raise the values before placing equipment in service (test wet equipment while drying out).
5. Fair or high values, previously well-maintained, but showing sudden lowering.	Make tests at frequent intervals until the cause of low values is located and remedied; or until the values have become steady at a lower level but safe for operation; or until values become so low that it is unsafe to keep the equipment in operation.

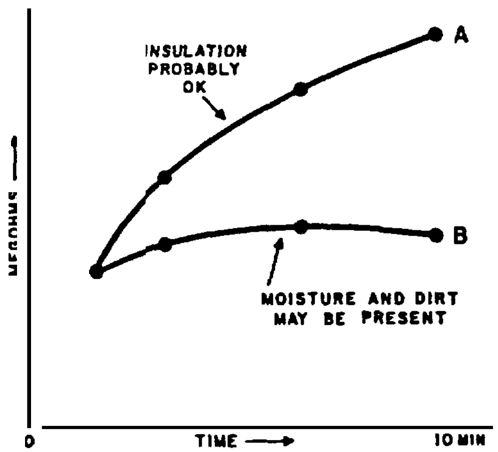

Figure14-3. Typical curves showing dielectri absorption effecting a time-resistance or double-mading test.

14-3. Protective relay testing.

Protective relays are used to detect and isolate system abnormalities with minimum disturbance to the rest of the electrical distribution system. The more common protective relays are the electro-mechanical types. In them, a mechanical element, such as an induction disk or magnetic plunger, moves in response to an abnormal change in a parameter of the eletrical system. This movement causes a contact in the control circuit to operate, tripping the circuit breaker. Protective relays should be maintained (in a 12- to 24-month maintenance cycle depending upon local operating and manpower conditions) to ensure their reliable performance. (See Section 15.5 of ANSI/IEEE Std 242-1986.)

a. Relay maintenance. The steps to take for relay maintenance are:

(1) The technician must understand the construction, operation and testing of the particular relay.

(2) The relay manufacturer's instruction bulletin should be available.

(3) The technician should be given the settings to be applied to each particular relay, and the test points. This data is often furnished on a time-current characteristic curve of a coordination study.

(4) A test instrument should be available as recommended by the manufacturer.

(5) Most protective relays can be isolated for testing while the electrical system is in norma operation. However, an operation of the breaker is required to ascertain that the operation of the relay contacts will trigger the intended reaction, such as to trip the associated circuit breaker.

b. The tests to be performed are determined by the relay to be tested. For electro-mechanical relays, inspection, testing and adjustment are recommended.

(1) *Inspection*. Each relay should be removed from its case for a thorough inspection and cleaning.

Table 14-2. Condition of insulation indicated by dielectric absorption ratios.

INSULATION COORDINATION	60/30-SECOND RATIO	10/1-MINUTE RATIO (POLARIZATION INDEX)
Dangerous		Less than 1
Questionable	1.0 to 1.25	1.0 to 2
Good	1.4 to 1.6	2 to 4
Excellent	Above 1.6 **	Above 4 **

*These values must be considered tentative and relative - subject to experience with the time-resistance method over a period of time.

**In some cases, with motors, values approximately 20% higher than shown here indicate a dry brittle winding which will fail under shock conditions or during starts. For preventative maintenance, the motor winding should be cleaned, treated, and dried to restore winding flexibility.

If the circuit is in service, remove one relay at a time so as no to totally disable the protection. Before the relay cover is removed, excessive dirt, dust and metallic material deposited on the cover should be noted and removed.Removing such material will prevent it from entering the relay when the cover is taken off. The presence of such deposits may indicate the need for some form of air filtering at the station. "Fogging" of the cover glass should be noted and cleared. Such fogging is, in some cases, a normal condition due to volatile materials being driven out of coils and insulation. However, if the fogging appears excessive, further investigation is necessary. A check of the ambient temperature and the supplied voltage and current must be compared to the nameplate or manufactured instruction book ratings.

(2) *Electrical tests.* Manually close (or open) the relay contacts and observe that they perform their required function; i.e., trip a breaker, reclose a breaker, etc. Apply prescribed settings or ascertain that they have been applied to the relay. Gradually apply current or voltage equal to the tap setting to the relay to verify that the pickup is within specified limits. If miscalibrated, the restraining spiral spring can be adjusted. The data that this test yields should be compared to previous data. Reduce the current or voltage until the relay drops out or resets fully. This test will indicate excess friction. Should the relay be sluggish in resetting or fail to reset completely, then the jewel bearing and pivot should be examined. A magnifying glass is adequate for examining the pivot, and the jewel bearing can be examined with the aid of a needle which will reveal any cracks in the jewel. Should dirt be the problem, the jewel can be cleaned with an orange stick while the pivot can be wiped clean with a soft, lint-free cloth. No lubricant should be used on either the jewel or pivot. Should evidence of overheating be found, the insulation should be checked and if brittle replaced. Withdrawal of the connection plug in drawout relays may reveal evidence of severe fault currents or contaminated atmospheres, either of which may indicate that a change in the maintenance schedule is necessary.

(3) *Mechanical adjustments.* All connections should be tight. If several connections are loose, excessive vibration may be indicated, and should be corrected. All gaps should be free of foreign materials, if not, inspection of the gasket is necessary. Contact gaps should be measured and the values compared with pervious measurements. Should there be a large variation in these measurements, excessive wear may be indicated, in which case the worn parts should be replaced. It may also be found that an adjusting screw has worked loose and must be retightened. This information should be noted on the test record. All contacts, except those not recommended for maintenance, should be burnished and measured for alignment and wipe. Relays that operate after a time delay when subjected to an overcurrent condition should have an operating time test performed. This test is made anywhere from two to ten times tap setting. The time it takes the relay to trip must coincide with the manufacturer's recommended operating times. If not, then relay adjustments should be made, if possible and the relay retested. Readjustments may be necessary until the

relay operates within acceptable limits. Tests should be made with the relay in its panel and case, and the time tests run at the calibrated setting. For precise testing procedures, manufacturer's instructions should be consulted. Some protective relays operate instantaneously; that is, with no intentional time delay. They should be set by test. Most types of protective relays have a combination target and seal-in unit. The target indicates that the relay has operated; the seal-in holds the relay contacts closed. It should be verified that the target is functional and that the relay will seal-in with the minimum specified DC current applied to the seal-in unit.

14-4. Equipment ground resistance testing.

An equipment ground is a connection to ground from one or more noncurrent-carrying metal parts of the equipment (para 8-2b). Instrument are available to determine if the grounding path is continuous and has sufficiently low resistance. When using these instruments, one should remember that although a high resistance value is an indication of a problem, for example a loose connection or excessive conductor length, a low resistance reading does not necessarily indicate the adequacy of the grounding path. A grounding path that is found to have a low resistance may not have sufficient capacity to handle large ground faults. Visual examinations and torquing connections are still needed to determine that adequacy of the grounding path.

14-5. System ground resistance testing.

A system ground is a connection to ground from one of the current-carrying conductors (para 8-2c). An adequately grounded system is necessary to provide for ground fault protections and to reduce the hazards of fire and shock to personnel. A system ground or earth resistance test has been developed to determine the effectiveness and integrity of the grounded system. Periodic testing is recommended based upon the importance of the ground system. The current flowing through an earth electrode encounters three basic resistive components: electrode; electrode-to-earth; and earth (fig 144). The earth resistance is the largest of the three resistance components. The earth resistance depends on the following:

a. Type of soil. As the soils composition varies so does the corresponding resistance values. Also as the soil becomes more closely packed, the resistance becomes less.

b. Moisture and temperature of soil. When a soil dries out, or its temperature is lowered, the soils resistance value increases (figs 14-5 and 14-6). Therefore, resistance values measured will vary with the seasons, and one earth resistance reading alone with not guarantee a safe earth ground.

c. *Grounding system. As* the grounding electrode is placed further into the earth the ground resistance decreases (fig 14-7), and there is less resistance change due to temperature and moisture variations. Changing the diameter of the electrode has little effect on ground resistance. An electrode (fig 148) is pictured surrounded by hemispheres of equal thickness and composed of the same type of soil. Each additional hemisphere away from the electrode increases in area. As the hemisphere's area increases, the resistance decreases- In effect, the earth resistance is the sum of all the hemisphere resistances. A point will be reached where the addition of new hemispheres will not effectively change the total resistance. This will be the value of the earth resistance.

(1) *Precautions.* All earth resistance testing methods can involve hazards to the operator. Precautions should be taken as follows:

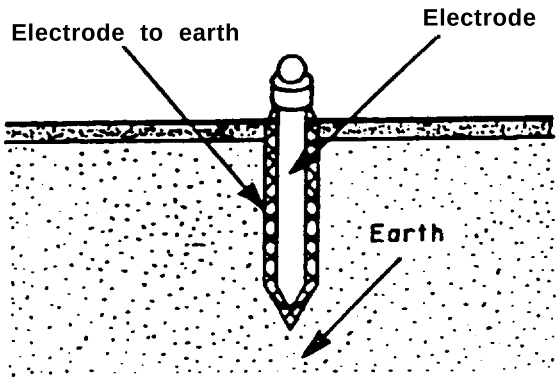

Figure 14-4. Resistive components of a made electrode.

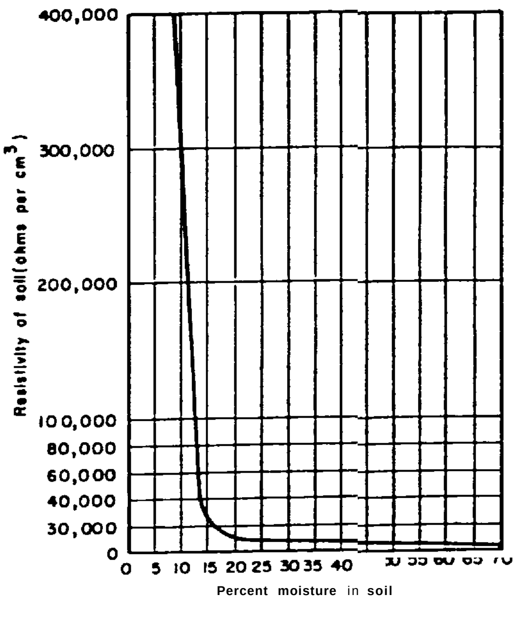

Figure 14-5. Soil resistivity vs. moisture content of red clay soil.

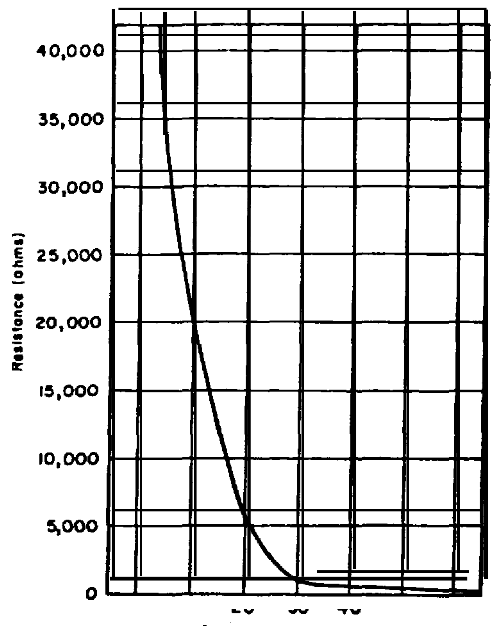

Figure 14-6. Soil resistance vs. temperature of clay soil.

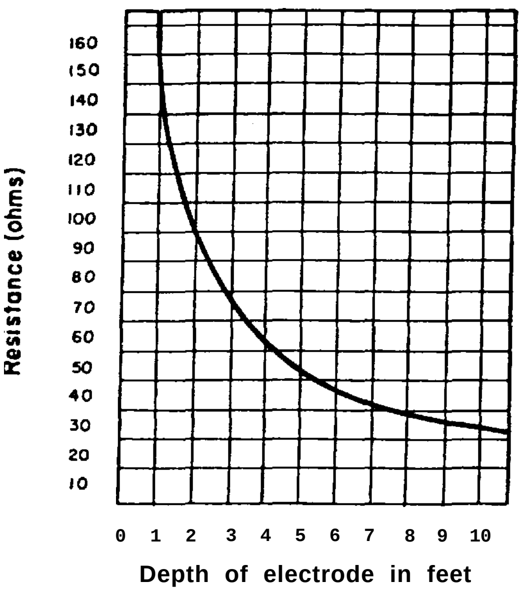

Figure 14-7. Soil resistance vs. depth of electrode.

(a) When testing earth resistance, remember that during fault conditions, dangerous voltages may exist between a system ground and a remote point being tested. Care should be taken when connecting leads and test equipment, Avoid as much contact with the leads and probes as possible.

(b) Most of the earth resistance is located close to the grounding system due to the "hemisphere effect". When a ground fault occurs, the majority of the voltage drop is close to the system. Caution should be used when approaching a live ground.

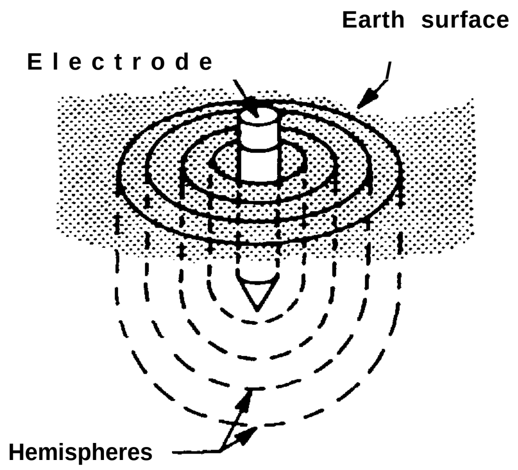

Figure 14-8. Earth electrode with hemispheres.

(c) At stations where the fence is not connected to the station ground, a dangerous voltage can develop under fault conditions between the fence and station ground. Do not touch both at the same time.

(d) Surge and switching effects in transmission lines may induce dangerous spikes in the test leads strung under the line. Care should be exercised in handling these test leads.

(e) Tests should not be performed during a thunderstorm.

(2) *Protection.* Rubber gloves, boats, an insulated platform, etc., capable of protecting the operator against full-line voltage, are recommended for protection.

(3) *Fall-of-potential method.* The fall-of-potential method is probably the most widely used and accepted of all methods available. It can be used most practically on small and medium sized systems. A ground resistance test set is used. Measure the earth resistance of the earth system (E) (fig 14-9). In this method, greater pin spacing is required for testing ground grids and multiple rod installations than for single rod testing. To accomplish this, current is supplied between the current electrode (CE) and the system E under test. A voltmeter measures the voltage drop between the potential electrode (PE) and the system. By moving the potential electrode between E and CE, various voltages will be recorded and corresponding resistance values found. When the resistance values are plotted versus distance, the earth resistance can be seen to increase as the potential electrode moves away from the system ground, but at a decreasing rate of change. This results because each new outer hemisphere of earth around the system E adds a smaller amount of resistance to the total earth resistance as previously discussed. At a point, usually

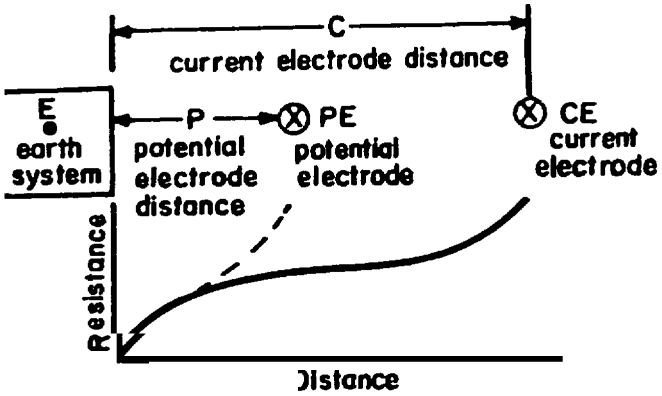

Figure 14-9. Fall-of-potential method graph.

about 62 percent of the total distance between the current probe and the system, the earth resistance should become almost constant. This is the point where the earth resistance of the system is most accurate.

14-6. Battery specific gravity test.

Great care should be exercised when sampling and handling battery electrolyte. Since it may contain acid it can cause irritation if it comes in contact with the skin, and could cause blindness if it were splashed in the eye. Electrolyte is also a conductor and can cause short circuits if splashed over the cell terminals. When specific gravity of a battery is being measured, wear acid resistant eye protection, gloves and apron. It is also available to wear rubber slippers or boots when working with batteries. When sampling the cells' electrolyte:

a. Place a hydrometer tube (or hose) firmly into the mouth of the cell electrolyte withdrawal tube (fig 14-10).

b. Slowly squeeze the hydrometer bulb so as to force air into the withdrawal tube, clearing it of electrolyte.

c. Release hand pressure on the hydrometer bulb allowing electrolyte to draw up into the glass barrel of the hydrometer. Sufficient electrolyte must be withdrawn to allow the hydrometer float to float freely.

d. The hydrometer must be held vertical such that the float is free and not in contact with the sides of the hydrometer barrel.

e. With hydrometer floating freely, read and record the float scale point at the true liquid level (fig 14-11). The level at point A is 1.210; at point B, where the float is lower in the liquid, the reading is 1.183.

14-7. Infrared inspection.

Infrared thermography is the process of making inframed radiation visible and measurable. This radiation is emitted by all objects as heat, which is constantly being absorbed and re-emitted by everything including ourselves. When an electrical connection is loose or corroded, it is said that the conductor has developed a high resistance connection. A high resistance connection produces heat which can be detected through infrared thermography. Loose connections should be tightened and corroded connections cleaned. Cables with poor insulation should be repaired or replaced. Infrared inspections of electrical equipment help to reduce the number of costly and catastrophic failures and unscheduled shutdowns. Such inspections performed by qualified and trained personnel on energized equipment may uncover potentially dangerous situations. Proper diagnosis and remedial action have also helped to prevent major losses. The instruments most suitable for infrared inspections are of the type that use a scanning technique to produce an image of the equipment being inspected. These devices display a picture, where the "hot spots" appear as bright spots. Infrared surveys may be performed by military facilities personnel if they own infrared imaging instruments and adhere to the manufacturer's instructions. Routine infrared surveys should be performed at the very least every year during periods of maximum possible loading. These surveys should be well documented and if critical, impending faults exist, the electrical supervisor should be notified and corrective actions taken.

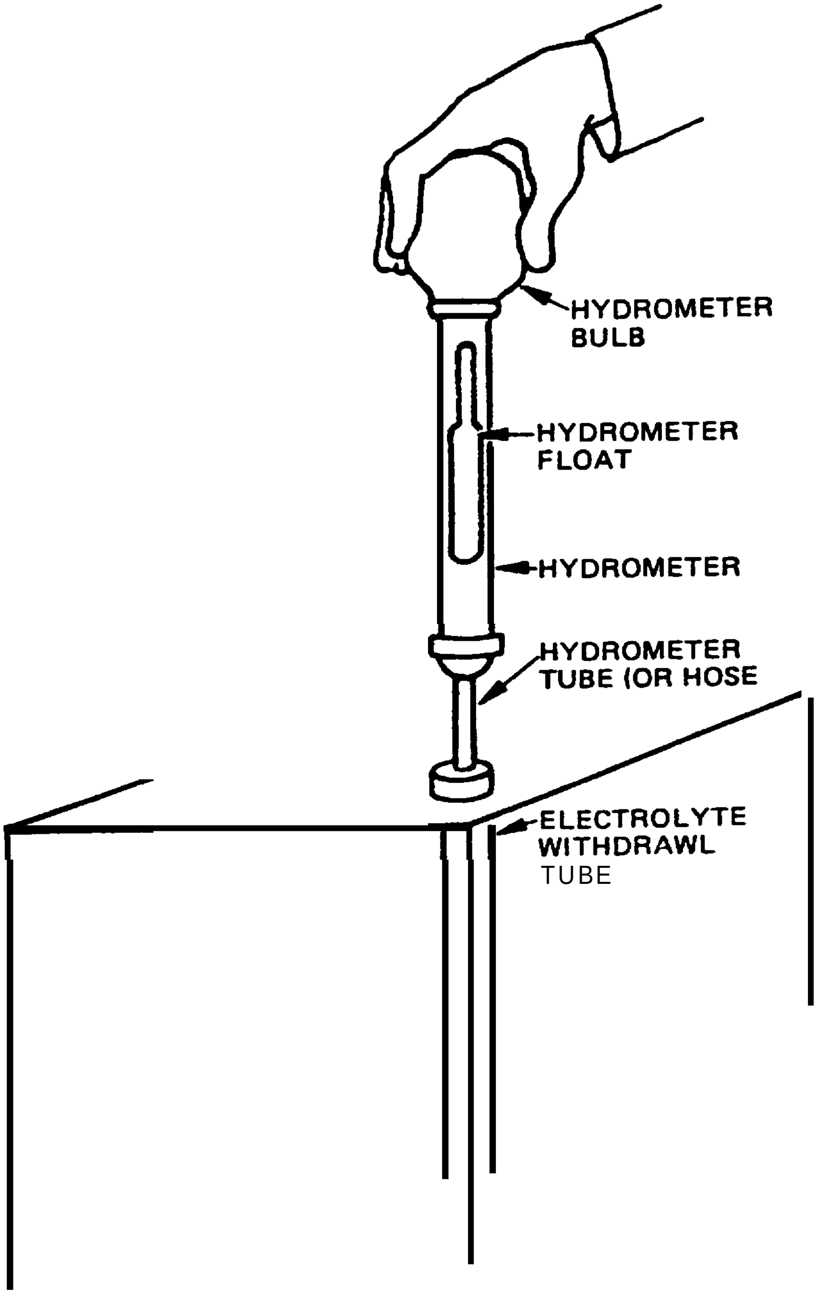

Figure 14-10. Sampling the cell electrolyte.

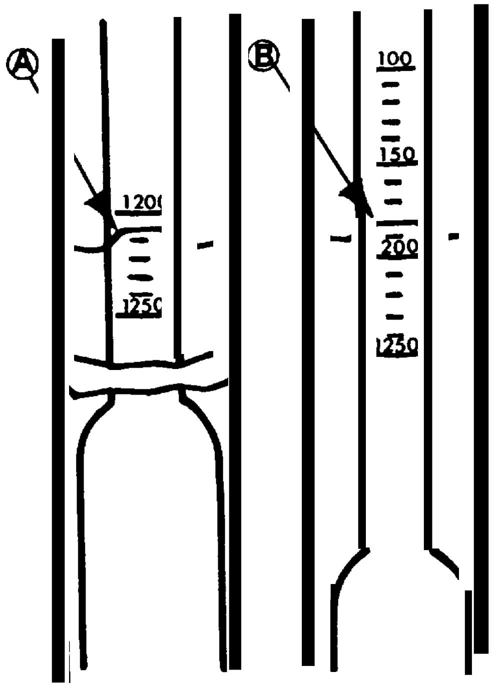

Figure 14-11. Reading the hydrometer flint.