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PRESSURE TESTING
CORRECTION OF PRESSURE MEASUREMENTS
GENERAL

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1. GENERAL

1.01 This is a new section containing general information regarding the correction of pressure measurements. Detailed instructions on the methods of determining these corrections and their application in pressure testing are covered in other sections.

1.02 Pressure measurements are generally made for comparison with other measurements which may have been taken under different conditions. When an accurate comparison is necessary the readings must be corrected for the effects of changes in temperature, changes in atmospheric pressure due to weather and altitude, as well as differences in cable elevation at the various valve points along the cable. For example, if a pressure measurement is made on a length of cable under certain temperature and atmospheric conditions and a later measurement made under different temperature and atmospheric conditions indicates a different pressure, the observed change in pressure may be due either to a fault in the sheath or to the

change in temperature and atmospheric pressure. However, if appropriate corrections are made, the corrected measurements will show whether or not there is a leak in the sheath.

1.03 In order to understand how corrections to pressure measurements are made and under what conditions it is necessary to make them, the following fundamentals should be thoroughly understood.

2. EFFECT OF TEMPERATURE

2.01 If the temperature of nitrogen or any other gas increases, the gas tends to expand; that is, take up more space. Since the space inside of a cable is fixed, the gas cannot take up more space so it builds up a greater pressure. Pressure increases with rising temperature and decreases with falling temperature.

2.02 If the temperature does not change uniformly throughout the entire length of a cable, the pressure change will not be uniform and there will be a movement of gas from the section of cable at the higher temperature and pressure toward the section of cable at the lower temperature and pressure. This movement will stop only when temperature changes cease, and after the pressure in the entire length of cable has again become equalized. In any section of cable, the average temperature change determines the average pressure change.

2.03 The pressures in cables maintained at 6 to 9 pounds per square inch vary from .15 to .3 pound for each 5 degrees change in temperature. Consequently, pressures measured at different temperatures must first be converted to their equivalent values at a common temperature before they can be compared directly. This is usually done by converting all pressure readings to their equivalent values at 60° F. This has been selected as a reference value because it is in about the middle of the temperature range normally encountered. As the reference value, it becomes the temperature at which normal cable maintenance and contactor operating pressures are specified.

3. EFFECT OF ATMOSPHERIC PRESSURE

3.01 Pressure readings made with a gauge or mercury manometer indicate the value by which the cable pressure exceeds the prevailing atmospheric pressure. The total, or absolute pressure, in a cable is the sum of gauge pressure and atmospheric pressure. Atmospheric pressure varies with weather conditions and with altitude. Even though there is no change in the pressure of the gas within a cable, a change in atmospheric pressure will change the gauge reading and indicate a change in cable pressure.

3.02 Atmospheric pressure is measured with a barometer and is generally expressed in inches of mercury. The normal atmospheric pressure at sea level is approximately 30 inches of mercury which is equal to about 15 pounds per square inch. A variation of one inch of mercury is, therefore, equivalent to a change of one-half pound in atmospheric pressure.

3.03 Normal changes in weather will produce atmospheric pressure variations of .1-inch of mercury or .05-pound an hour. It is not unusual for the barometric pressure at a given location to vary by one inch of mercury or 1/2 pound from day to day and by more than two inches of mercury or 1 pound over a period of several days. Under storm conditions, the barometer may vary by the latter amount in a few hours.

3.04 As these changes in atmospheric pressure occur, the gauge or manometer readings of a constant absolute pressure within a cable will vary accordingly. For example, a measurement of 6.5 pounds taken when the barometer reads 30 inches is equivalent to a measurement of 7.0 pounds when the barometer reads 29 inches. This explains why pressure measurements taken on consecutive days, even though corrected for temperature variation, sometimes make it appear that a cable has gained pressure. Operating in the reverse direction, this effect exaggerates pressure losses. For this reason, pressure readings taken at different times under different atmospheric pressures must first be converted to their equivalent values at a common atmospheric pressure before they can be compared directly.

3.05 The normal atmospheric pressure of 30 inches of mercury at sea level is due to the weight of the layer of air which surrounds the earth. At elevations above sea level there is less air overhead and, therefore, less weight and less atmospheric pressure. Actually, the atmospheric pressure decreases by about one inch of mercury for each 1,000 feet increase in altitude. For example, at Reno, Nevada (4,000 feet above sea level) the normal atmospheric pressure is equal to about 26 inches of mercury. However, normal changes in weather produce about the same variations in atmospheric pressure at the higher altitudes that occur at sea level.

3.06 The universal use of the barometer to predict weather conditions has led the manufacturers to equip barometers with movable scales graduated to read from about 27 inches to 31 inches of mercury. Whether these instruments are used at high elevations or at sea level the 30-inch graduation is generally adjusted so that it corresponds to the normal atmospheric pressure at the location of the barometer, regardless of

altitude. U. S. Weather Bureau stations are prepared to furnish barometric readings adjusted to the 30-inch (sea level) base.

3.07 Regardless of the altitude of a cable, the effect of variations in atmospheric pressure due to weather conditions can be eliminated by converting all pressure readings to their equivalent values under normal atmospheric pressure of 30 inches of mercury (sea level base). As a reference value, this is the barometric reading at which normal cable maintenance and contactor operating pressures are specified.

4. EFFECT OF ALTITUDE

4.01 As stated previously, normal atmospheric pressure is equal to 30 inches of mercury or about 15 pounds pressure at sea level and decreases by about one inch of mercury or one-half pound pressure for each 1,000 feet increase in altitude. Thus, at Reno, Nevada (4,000 feet above sea level), the normal atmospheric pressure of 26 inches of mercury is equal to about 13.0 pounds.

4.02 Gauge or manometer readings of a given absolute pressure will be influenced accordingly. For example, the gauge pressure on a reel of cable is measured as 6 pounds at sea level. The cable is shipped to a point whose elevation is 3,000 feet above sea level. On arrival, the gauge pressure (assuming no leakage and comparable temperature and weather conditions) will measure 7.5 pounds. In both cases, the absolute cable pressure is the same (21.0 pounds) but at sea level the normal atmospheric pressure is 15.0 pounds, whereas, at 3,000 feet, it is 13.5 pounds.

4.03 Consequently, pressure readings on a reel of cable, terminal or load coil case made at different altitudes must first be converted to their equivalent values at a common altitude before they can be compared. This may be done by converting the pressure readings to their equivalent values at sea level. The measurements referred to are usually made in connection with construction tests of individual reels of cable; the method of conversion is described in the section covering such tests.

4.04 In mountainous country, different parts of the same gas section may be at considerably different altitudes. In such cases, the weight of the gas in the cable causes a greater pressure at low elevations in the gas section than exists at the higher elevations in the same gas section. If such a gas section is completely equalized and has no leaks, the cable pressure will vary as the altitude varies and will be less at the higher eleva-

tions. Unless a correction is applied, the pressure gradient for the gas section would indicate a leak at all the hill tops.

4.05 This decrease in pressure of the nitrogen gas in the cable with increase in elevation varies with the cable pressure. For example, at a 9-pound measured pressure, the decrease is about .8 pound in absolute pressure (total pressure inside sheath) for each 1,000 feet. At a 6-pound pressure, the decrease is about .7 pound for each 1,000 feet. Also, as stated previously, the atmospheric pressure (air pressure outside sheath) decreases at the rate of about .5 pound for each 1,000 feet increase in elevation. These factors must be taken into account in making routine pressure measurements and in locating leaks on completed gas sections. For example, if a buried cable charged to 9 pounds and containing no leaks is allowed to stand until complete equalization has taken place, the cable pressure as read by a manometer will vary about .1 pound for each 300 feet difference in elevation between valve points. Variations of this amount or greater are of concern when making routine measurements in a gas section in mountainous country. Even smaller differences in elevation are significant in the location of small leaks in underground or buried cable.

4.06 Consequently, pressures measured at different altitudes must first be converted to their equivalent values at a common altitude before they can be compared directly. This is usually done by converting all pressure readings in a gas section to their equivalent values at a reference elevation equal to or slightly below the altitude of the lowest point in the gas section.

5. WHEN CORRECTIONS SHOULD BE MADE

5.01 Corrections are made in order to improve the accuracy of pressure measurements and permit comparison of measurements which may be made at different times under different conditions. Good judgment is necessary in order to determine when, and to what extent, the corrections outlined in the following should be applied to pressure measurements.

5.02 **Temperature Correction:** Temperature correction **is required** when measurements are made for the following purposes:

(1) Determining rate of loss in a gas section or in a reel of cable, or some piece of equipment not connected to a cable, such as a loading coil case. This is necessary because two sets of measurements are to be compared and the effect of temperature should be taken into account to permit direct comparison of the readings.

(2) Adjusting contactors, or contactor-terminals.

(3) Charging or recharging cables.

(4) Determining the exact amount of gas in a cylinder. Day-to-day work does not require that the exact amount of gas in a cylinder be known but certain special tests, such as determining pneumatic resistance, may require this knowledge.

5.03 Temperature corrections **are not necessary** when pressure measurements are taken simultaneously or within a relatively short period of time for the purpose of plotting pressure gradients in leak location work. In fact, any attempt to compensate for temperature, is likely to reduce the accuracy of the pressure measurements.

5.04 **Atmospheric Pressure Correction:** Corrections for the effect of atmospheric pressure changes due to weather conditions are important, and should be considered when making pressure measurements for the purpose of determining rate of loss, adjusting contactors or contactor-terminals, charging or recharging cables, and at other times when two measurements made under different weather conditions are to be compared.

5.05 Pressure measurements made for the purpose of locating a leak are generally made within a short interval of time, during which little or no atmospheric pressure changes occur and hence no correction is necessary. Leak location work with a gauge or mercury manometer should not be undertaken during rapidly changing weather conditions. The absolute manometer is not affected by changes of atmospheric pressure.

5.06 **Altitude Correction:** Good judgment is necessary in order to determine when and to what extent altitude correction should be applied. Measurements are generally recorded to the nearest .1 pound when making routine readings and when charging and recharging cables. In these cases, altitude correction should be applied whenever there is a difference in elevation of about 150 feet or more between the highest and lowest pressure measuring points.

5.07 Smaller differences in elevation will be significant in the location of a small leak in an underground or buried cable. When a mercury manometer is employed and accuracy is required to .01 pound, altitude correction should be applied for differences in elevation of 20 feet or more in the section under consideration. Pressure measurements made with a precise absolute manometer which is calibrated to .001 pound should be corrected for differences of one foot or more in elevation.

5.08 No altitude correction is necessary when checking or adjusting the operating pressures of contactors as all contactors are set to operate at a normal value of 6 or 3 pounds above atmospheric pressure regardless of altitude. However, it

should be recognized that the cable pressure will be less in the higher portions of a gas section and, therefore, the contactors in the higher portions will have less operating margin.

5.09 Altitude correction is necessary when the pressure of a reel of cable or other material measured at one elevation is to be compared to a subsequent measurement made after the cable or other material has been moved to a different elevation.

6. SUMMARY OF CORRECTIONS

6.01 The table on the following page lists the various purposes for which pressure measurements are taken and indicates which corrections are required.

SUMMARY OF PRESSURE MEASUREMENT CORRECTIONS

Nature of Measurements	Correction to be made			Remarks
	Atmospheric Pressure	Temperature	Altitude	
1. Routine readings.	Yes. Convert to normal atmospheric pressure (30 inches at sea level). See section pertaining to "Atmospheric Pressure."	Yes. Convert to 60° F. See section covering "Temperature."	Yes, if considerable differences in elevation (150 ft. or more) exist in gas section. See section concerning "Altitude."	——
2. Charging and recharging (setting of regulators).	Yes. Use barometer reading for day tanks are connected. See section pertaining to "Atmospheric Pressure."	Yes. Use average temperature expected during charging interval. See section covering "Temperature."	Yes, if considerable differences in elevation (150 ft. or more) exist in gas section.	See section on "Charging Cables with Gas" for charging procedure.
3. Contactor adjustment.	Yes. See section pertaining to "Atmospheric Pressure."	Yes. See section covering "Temperature."	No.	See section covering "Description and Maintenance of Contactors and Contactor-Terminals" for method of adjustment.
4. Nitrogen cylinder volume.	No.	Yes. See section covering "Temperature."	No.	——
5. Leak locating.	No.	No.	Yes. See section concerning "Altitude."	Altitude correction not required on large leaks when differences in elevation are small.
6. Pressure measurements on reels of cable, load cases, terminals, etc., before splicing.	Yes. See Remarks.	Yes. See Remarks.	Yes. See Remarks.	Refer to section covering "Construction Tests" for method of applying correction.
7. Pneumatic resistance tests.	No.	Yes, when determining cylinder volume at start and end of test. See section covering "Temperature."	No.	Covered in AG Section "Determination of Flow Characteristics of Cables." Refer to Engineering Department.