# CABLE PRESSURE SYSTEMS CORRECTION OF PRESSURE MEASUREMENTS

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١.	GENERAL		

1.01 This section describes the procedures required for converting cable pressure measurements from gauge pressure, as indicated by measuring with a C pressure gauge, to an equivalent value at a nominal temperature (60°F) and an absolute pressure. Absolute pressure (psia) is the sum of the gauge pressure and the atmospheric pressure in pounds per square inch (psi). This conversion

is necessary when plotting pressure measurements for the purpose of locating leaks in pressurized cables.

- 1.02 This section is issued to consolidate and update information previously covered in Sections 637-400-011, -501, -502, and -503.
- 1.03 Generally, pressure measurements are made and compared with previous measurements which may have been taken under different conditions. When an accurate comparison is necessary, the readings must be corrected for the effect of changes in temperature, atmospheric pressure, and altitude.
- 1.04 In order to understand under what conditions pressure measurement corrections are required and how they are made, the following fundamentals should be understood thoroughly:
  - · Effect of temperature
  - · Effect of atmospheric pressure
  - · Effect of altitude.

#### 2. TEMPERATURE

#### **EFFECT OF TEMPERATURE**

- 2.01 When the temperature of air or other gases increase, they tend to expand and take up more space. Since the space inside a cable is fixed, the air cannot take up more space; therefore, the 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 air from the section of cable at the higher temperature toward the section at the lower temperature. This movement will stop only when temperature changes cease and pressure

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in the entire length of cable is equalized. In any section of pressurized cable, the average temperature change determines the average pressure change.

2.03 The pressures in cables maintained at 6 to 9 psi vary from 0.15 to 0.30 psi for each 5-degree change in temperature. Consequently, pressures measured at different temperatures first must be converted to their equivalent values at a reference temperature before they can be compared directly. This usually is done by converting all pressure readings to their equivalent values at 60°F. The value of 60°F is selected as a reference value because it is approximately the middle of the temperature range normally encountered. It is specified as the reference temperature for normal cable maintenance and contactor operating pressures.

#### MEASUREMENT OF TEMPERATURE

- 2.04 For pressure testing purposes, temperature is determined by measuring the ambient or ground temperature, using a thermometer having a range of 0° to 150°F. When measuring temperature, the thermometer should not be held in the hand. Approximately 5 minutes should be allowed for the thermometer to record the correct temperature.
- 2.05 When measuring the temperature of cable on reels, loading coil cases, etc, located in the sun, the thermometer should be on the sunny side, with its tube facing the sun. If they are in the rain, the thermometer is placed so that the rain strikes it directly. If they have recently been moved, allow sufficient time to permit the material to reach ambient temperature before making temperature measurements.
- 2.06 For aerial cable, temperature measurements are made at each point where a pressure reading is made. If the sun is shining, suspend the thermometer from the cable or a pole so that the tube is in and facing the sun (whether the pressure measuring point is in the sun or shade). If the sun is not shining, face the tube in the general direction of where the sun should be at that time of day; if raining, place the thermometer where the rain strikes it directly.
- 2.07 When temperature measurements are required for underground cable in conduit or buried cable, generally, they need to be made at only a few valve points. On individual reel lengths after placing and loading sections during construction of

a cable, a temperature measurement at one point is sufficient. For tests on completed cable sections, temperature measurements can be made at valve locations at intervals of 12,000 to 18,000 feet.

- 2.08 To measure the temperature of underground cable, fasten the thermometer to a duct rod and insert it 6 to 9 feet inside the duct containing the cable to be measured. If the conduit is filled with water or there is no room to insert the duct rod, suspend the thermometer in the manhole at approximately the same level as the cable.
- 2.09 Temperature measurements on buried cable can be made by inserting the thermometer in a hole (1 to 2 feet in depth) formed by driving a rod or bar into the ground approximately 10 feet to the side of the cable run. Suspend the thermometer in the hole for approximately 5 minutes, then withdraw and observe its reading.
- the temperature of a nitrogen cylinder, the thermometer should be placed in a vertical position alongside the cylinder. If the cylinder is in the sun, place the thermometer on the sunny side with its tube facing the sun. If the cylinder is in the rain, the thermometer should be placed so the rain strikes it directly. Recently moved cylinders should be allowed time to adjust to temperature at the new location before measurement is made.

#### TEMPERATURE CORRECTIONS

- **2.11** Temperature correction *is required* when pressure measurements are made for the following purposes:
  - (a) Determining rate of air loss in a cable section, in a reel of cable, or in some piece of equipment not connected to a cable, such as a load 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.
  - (b) Adjusting cable pressure monitoring devices.
  - (c) Charging or recharging cables on reels, or during construction.
  - (d) Determining the exact amount of gas in a cylinder. Day-to-day operations do not

require that the exact amount of gas in a cylinder be known; but certain special tests, such as determining pneumatic resistances, may require this information.

2.12 Temperature corrections are not necessary when pressure measurements are taken simultaneously or within a relatively short period of time. In fact, any attempt to compensate for

temperature is likely to reduce the accuracy of the pressure measurements.

## A. Correction for Cable Temperature

2.13 Measured cable pressures can be converted to their equivalent values at 60°F, or to any other temperature by use of Table A.

TABLE A

CABLE TEMP. DEGREES F.				OF 30	NG NOF	MAL SEA	URES AT V LEVEL AT LY OR 15 P POUNDS	MOSPHE OUNDS P	RIC PRES	SURE		
110	4.7	5.8	6.9	8.0	9.1	10.2	11.3	12.4	13.5	14.6	15.7	16.8
105	4.5	5.6	6.7	7.8	8.9	10.0	11.1	12.1	13.2	14.3	15.4	16.5
100 95	4.4	5.4 5.3	6.5 6.3	7.6 7.4	8.7 8.5	9.7 9.5	10.8 10.6	11.9 11.7	13.0 12.7	14.1 13.8	15.1 14.9	16.2 15.9
90	4.0	5.1	6.1	7.2	8.3	9.3	10.4	11.4	12.5	13.5	14.6	15.7
85	3.9	4.9	5.9	7.0	8.0	9.1	10.1	11.2	12.2	13.3	14.3	15.4
80	3.7	4.7	5.8	6.8	7.8	8.9	9.9	11.0	12.0	13.0	14.1	15.1
75	3.5	4.5	5.6	6.6	7.6	8.7	9.7	10.7	11.7	12.8	13.8	14.8
70	3.3	4.4	5.4	6.4	7.4	8.4	9.5	10.5	11.5	12.5	13.5	14.6
65	3.2	4.2	5.2	6.2	7.2	8.2	9.2	10.2	11.2	12.3	13.3	14.3
60	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0
55	2.8	3.8	4.8	5.8	6.8	7.8	8.8	9.8	10.8	11.7	12.7	13.7
50	2.7	3.6	4.6	5.6	6.6	7.6	8.5	9.5	10.5	11.5	12.5	13.4
45	2.5	3.5	4.4	5.4	6.4	7.3	8.3	9.3	10.3	11.2	12.2	13.2
40	2.3	3.3	4.2	5.2	6.2	7.1	8.1	9.0	10.0	11.0	11.9	12.9
35	2.1	3.1	4.1	5.0	6.0	6.9	7.9	8.8	9.8	10.7	11.7	12.6
30	2.0	2.9	3.9	4.8	5.7	6.7	7.6	8.6	9.5	10.5	11.4	12.3
25	1.8	2.7	3.7	4.6	5.5	6.5	7.4	8.3	9.3	10.2	11.1	12.1
20	1.6	2.6	3.5	4.4	5.3	6.3	7.2	8.1	9.0	9.9	10.9	11.8
15	1.5	2.4	3.3	4.2	5.1	6.0	7.0	7.9	8.8	9.7	10.6	11.5
10	1.3	2.2	3.1	4.0	4.9	5.8	6.7	7.6	8.5	9.4	10.3	11.2
5	1.1	2.0	2.9	3.8	4.7	5.6	6.5	7.4	8.3	9.2	10.1	11.0
0	1.0	1.8	2.7	3.6	4.5	5.4	6.3	7.1	8.0	8.9	9.8	10.7
<b>-</b> 5	0.8	1.7	2.5	3.4	4.3	5.2	6.0	6.9	7.8	8.7	9.5	10.4
-10	0.6	1.5	2.3	3.2	4.1	4.9	5.8	6.7	7.5	8.4	9.3	10.1

2.14 Table A graduations are based on the variation of absolute pressure with temperature, but are expressed in terms of average gauge pressure at sea level. An error results when this table is used to convert pressure readings taken at higher elevations. However, the error introduced is small (less than 0.1 psi) and may be neglected in ordinary pressure maintenance operations requiring temperature correction.

#### B. Correction for Cylinder Temperature

- 2.15 The pressure of gas in a cylinder varies with changing temperature. Cylinder pressure is indicated by the high-pressure gauge of the regulator. This gauge is calibrated to indicate the volume of gas contained in the cylinder, equivalent cubic feet of gas at sea-level pressure and 60°F. Readings taken at other cylinder temperatures are in error (readings increase with rising temperature).
- 2.16 At temperatures other than 60°F, indicated volumes on the high-pressure gauge of the regulator can be converted to equivalent volumes at 60°F by the use of Table B.

#### 3. ATMOSPHERIC PRESSURE

#### EFFECT OF ATMOSPHERIC PRESSURE

- 3.01 Atmospheric pressure is measured with a barometer and is expressed in inches of mercury. Atmospheric pressure at sea level is approximately 30 inches of mercury, which is equivalent to approximately 15 psi. A variation of 1 inch of mercury is equivalent to a change of 0.50 psi in atmospheric pressure.
- 3.02 Changes in weather conditions may result in atmospheric pressure variations of 0.1 inch of mercury or 0.05 psi change in a period of 1 hour. Barometric pressure at a given location may vary by 1 inch of mercury from day to day and by more than 2 inches of mercury over a period of

several days. Under storm conditions, the pressure may vary by the latter amount in a few hours.

- the gauge pressure of a cable will vary accordingly. For example, a measurement of 6.5 psi taken when the barometer reads 30 inches is equivalent to a measurement of 7.0 psi when the barometer reads 29 inches. This is the reason that pressure measurements taken on consecutive days, although corrected for temperature variation, may appear to show that a cable has gained pressure. Operating in the reverse direction, this effect exaggerates pressure losses. Before pressure readings (taken under different atmospheric conditions) can be compared, they must be converted to their equivalent values at a common atmospheric pressure.
- 3.04 The normal atmospheric pressure of 30 inches of mercury at sea level is due to the weight of the layer of air which envelopes the earth. At elevations above sea level there is less air overhead, and therefore less atmospheric pressure. Atmospheric pressure decreases approximately 1 inch of mercury for each 1000 feet increase in altitude. Normal weather changes produce about the same atmospheric pressure variations at higher altitudes as at sea level.
- 3.05 Barometers are equipped with movable scales graduated to read from approximately 27 to 31 inches of mercury. Regardless of the altitude, the 30-inch graduation generally is adjusted to correspond to the normal atmospheric pressure at the location of the barometer. U. S. Weather Bureau Stations are prepared to furnish barometric readings adjusted to the 30-inch (sea-level) base.
- 3.06 Atmospheric pressure variations caused by weather conditions can be compensated for by converting all pressure readings to their equivalent values under normal atmospheric pressure of 30 inches of mercury (sea-level base). It is specified as the reference atmospheric pressure for normal cable maintenance and contactor operating pressures.

TABLE

TEMP. DEG. F.							CUE									T CYLII ESSURI		60°F.				E	TEMP DEG. F
125 120	34 34	46 45	57 56	68 67	80 79	91 90	103 102	115 113	126 125	138 137	149 148	161 159	173 171	185 183	196 194	208 206	220 217	2230 2200	2340 2310	2460 2440	2530 2500	2590 2560	125 120
115 110	34 33	45 44	56 55	67 66	78 78	90 89	101 100	112 111	124 122	136 134	147 145	158 156	170 168	181 179	192 190	204 201	215 213	2180 224	2290 2270	2410 2380	2470 2440	2530 2510	115 110
105 100	33 33	44	55 54	66 65	77 76	88 87	99 98	110 109	121 120	133 131	144 142	155 153	166 164	177 176	188	199 197	211 208	222 220	2240 2220	2360 2330	2420 2390	2480 2450	105
95	32	43	53	64	76	86	97	108	119	130	141	151	163	174	184	195	206	217	2190	2300	2360	2420	95
90 85	32 32	43 42	53 52	64	75 74	85	96	107	118	129	139	149	161	172	182	193	204	215	225	2270	2330	2390	90
80	31	42	52	63 63	73	85 84	95 94	106 105	116	127 126	138 136	148 146	159 157	170 168	180 178	191 189	201 199	212 210	222 220	2250 2220	2300 2270	2360 2330	85 80
75	31	41	51	62	72	83	93	103	114	124	135	145	155	166	176	187	197	207	217	2200	2250	2300	75
70 65	31 30	41	51 50	61	71 71	82 81	92 91	102 101	112 111	123 121	133	143 141	154 152	164 162	174 172	185 182	195 192	205 203	215 213	225 223	2220 2200	$\frac{2280}{2250}$	70 65
60	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	225	2220	60
55	30	40	49	59	69	79	89	99	109	119	129	138	148	158	168	178	188	198	207	217	222	2190	55
50 45	29 29	39 39	49 48	59 58	69 68	78 77	88 87	98 97	107 106	117 116	127 126	137 135	146 145	156 154	166 164	176 174	185 183	195 193	205 202	215 212	220 217	225 222	50 45
40	29	38	48	57	67	77	86	95	105	115	124	133	143	152	162	171	181	190	199	209	214	219	40
35 30	28 28	38 37	47	57 56	66 65	76 75	85 84	94	104	113	122 121	132 130	141 139	150 148	159 157	169 167	179 176	188 185	197	207 204	211 209	216 213	35 30
25	28	37	46	. 55	65	74	83	92	101	110	119	129	138	147	155	165	174	183	192	201	206	210	25
20 15	27 27	36 36	46 45	55 54	64 63	73 72	82 81	91 89	100	109 108	118 116	127 125	136 134	145 143	153 151	162 160	171 169	180 178	189 187	198 195	203 200	207 204	20 15
10	27	36	45	53	62	71	80	88	97	106	115	123	132	141	149	158	167	175	184	193	197	201	10
5 0	26 26	35 35	44	53 52	62 61	70 69	79 78	87 86	96 95	105	113 111	121 120	130 129	139 137	147 145	156 153	164 162	173 170	181 179	190 187	194 191	198 195	5 0
5 10	26 25	34 34	43 42	51 51	60 59	68 67	77 76	85 84	93 92	102 100	110	118	127 125	135 133	143	151	159 157	168 165	176 173	184	189 186	192 189	-5 -10

Instructions:

\*2220 pounds, 60°F. = 230 cu ft

<sup>(1)</sup> Read across line representing measured cylinder temperature and determine column in which observed volume reading appears on that line. Then read vertically in column to line representing 60° F. cylinder temperature. True volume of atmospheric gas in cylinder appears in column opposite 60° F. temperature.

<sup>(2)</sup> The volume scale of the high pressure gauge does not extend above 225 cubic feet. To obtain volume readings above end of scale, observe cylinder pressure and read across line representing measured cylinder temperature to column in which observed pressure reading appears on that line. Then proceed

#### MEASUREMENT OF ATMOSPHERIC PRESSURE

- 3.07 Barometer readings generally can be obtained from the nearest weather bureau or airport. Where this is found impracticable, barometers may be installed at the test desk or at other offices. These local barometers should be adjusted to read in accordance with weather bureau and airport barometers.
- 3.08 A barometer reading should be obtained each day that pressure measurements are made, and as close to the time of the measurements as practicable. Where a series of pressure measurements is to be compared, all barometer readings used to correct such measurements should be obtained from the same source. Except during periods of rapidly changing weather, barometer readings from a particular source may be applied to correct pressure readings taken within 50 to 75 miles of that source.

### ATMOSPHERIC PRESSURE CORRECTIONS

- 3.09 Corrections for the effect of atmospheric pressure changes should be considered when making pressure measurements for the purpose of:
  - (a) Determining rate of air loss
  - (b) Adjusting cable pressure monitoring devices
  - (c) Charging or recharging cables on reels, or during construction.
- 3.10 Pressure measurements made for the purpose of locating a leak generally are made within a short interval of time, during which little or no atmospheric pressure changes occur; and hence, no correction is necessary.
- 3.11 Measured pressures can be converted to their equivalent values in psi at normal barometric pressure of 30 inches of mercury as follows:
  - (1) Calculate the difference between 30 inches and the barometer reading in inches of mercury.
  - (2) Divide this difference by two (1 inch of mercury is equivalent to approximately 1/2 pound pressure).

(3) Add the value found in (2) to the pressure reading if the barometer reads more than 30 inches; subtract the value found in (2) if the barometer reading is less than 30 inches.

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- 3.12 Example: Assume that pressure readings have been made to determine the rate of air loss in a cable section. The first set of readings was found to average 6.8 psi at 60°F, with a barometer reading of 29.6 inches. A second set of readings, taken 10 days later, indicates an average pressure of 6.4 psi at 60°F, with a barometer reading of 30.2 inches.
  - (1) First, convert the average pressure found for the *first set of readings* to normal barometric pressure. Subtract 29.6 inches from the normal 30.0 inches and divide this value by two to find:

$$\frac{30.0-29.6}{2}$$
 = 0.2 psi.

(2) Since the barometer reading was less than 30 inches, subtract the value found in (1) from the average pressure reading:

$$6.8 - 0.2 = 6.6$$
 psi.

(3) Next, convert the average pressure found for the **second set of readings** to normal barometric pressure. Subtract the normal 30.0 from 30.2 and divide this value by two to find:

$$\frac{30.2 - 30.0}{2} = 0.1 \text{ psi.}$$

(4) Since the barometer reading was greater than 30 inches, add the value found in (3) to the average pressure reading:

$$6.4 + 0.1 = 6.5$$
 psi.

(5) The pressure loss in 10 days is:

$$6.6 - 6.5 = 0.1$$
 psi.

(6) The pressure loss in 30 days would be:

$$0.1 \quad \left(\frac{30}{10}\right) = 0.3 \text{ psi.}$$

3.13 If correction for variation in atmospheric pressure had been omitted in the example given in 3.12, the computed loss would have been:

$$6.8 - 6.4 = 0.4 \text{ psi } (10\text{-day period})$$

0.4 
$$\left(\frac{30}{10}\right) = 1.2 \text{ psi (30-day period)}.$$

#### 4. ALTITUDE

### EFFECT OF ALTITUDE

- 4.01 As stated previously, normal atmospheric pressure at sea level is equal to 30 inches of mercury or approximately 15 psi and decreases approximately 1 inch of mercury or 0.50 psi for each 1000-foot increase in altitude. Thus, at 4000 feet above sea level, the normal atmospheric pressure is 26 inches of mercury, which is equivalent to approximately 13 psi.
- 4.02 Gauge or manometer readings of a given absolute pressure will be influenced accordingly. For example, the gauge pressure of a reel of cable is measured as 6 psi at seal level. The cable is shipped to a point 3000 feet above sea level. On arrival, the gauge pressure (assuming no leakage and comparable temperature conditions) should measure 7.5 psi. In both cases, the absolute cable pressure is the same (21.0 psia). At sea level the normal atmospheric pressure is 15.0 psi.

$$15.0 \text{ psi} + 6.0 \text{ psi} = 21.0 \text{ psia.}$$
 Whereas, at 3000 feet, it is  $13.5 \text{ psi} + 7.5 \text{ psi} = 21.0 \text{ psia.}$ 

4.03 Consequently, pressure readings on a reel of cable, load coil case, etc, made at different altitudes must 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 value at sea level.

when a completed cable section is placed, at considerably different altitudes, in mountainous country. In such cases, pressure measurements will read higher at the lower elevation than at the higher elevations due to the gravitational pull on the air inside the cable. For example, a buried cable charged to 9 psi will vary approximately 0.1 psi per 300-foot difference in elevation.

#### MEASUREMENT OF ALTITUDE

- 4.05 Ordinary Measurements: These measurements apply only in correcting pressure measurements taken with a C pressure gauge or a mercury manometer.
- 4.06 In order that pressure measurements made at different elevations can be converted to their equivalent values at a common elevation, the elevation of all valve points in a cable section must be determined. In general, this should be done whenever there is a difference in elevation of approximately 150 feet or more between the highest and lowest valve points in the cable section.
- 4.07 The elevation of each valve point should be determined to an accuracy of ±10 feet by use of a surveyor level or hand level, or by other approved instruments such as precise altimeters.
- 4.08 When determining elevation of a buried cable section in mountainous country, it is desirable to obtain the elevation of each cable marker along the route in addition to the elevation at valve points. These marker elevations are shown on the plant records for pressure maintenance purposes.
- 4.09 When temporary valves are installed for leak location measurements, the elevations should be determined at that time. The known elevation of a regular valve point or marker can be used as the base and starting point of the survey.
- 4.10 If the elevation of a regular valve point or marker is not known, an assumed elevation can be used as the base and starting point for the survey of elevations for leak location measurements.
- 4.11 Precise Measurements: These measurements apply only in correcting

pressure measurements taken with precision instruments that measure absolute pressures to the nearest 0.001 psi, such as the Type FA-176021 W. and T. manometer.

- 4.12 When making precise measurements at different elevations, determine the elevation differences between the temporary valve points where measurements are made for leak location purposes. This is done whenever there is a difference in elevation of 1 foot or more between the lowest and highest valves at which pressure measurements are taken.
- 4.13 The difference in elevations between each of the temporary valve points and the base valve (lowest valve point) must be determined to an accuracy of approximately 1 foot. These elevations are determined for each valve at the point where the precision instrument will be placed when the pressure measurement of that valve is taken. Elevations may be determined to the accuracy required by the use of a surveyor level, builder level, or suitable equivalent.

#### **ALTITUDE CORRECTIONS**

- 4.14 Good judgment is necessary in order to determine when and to what extent altitude correction should be applied. Measurements generally are recorded to the nearest 0.1 psi when making routine readings and charging and recharging cables. In these cases, altitude correction should be made whenever there is a difference in elevation of about 150 feet or more between the highest and lowest pressure measuring points.
- 4.15 Smaller differences in elevation will be significant in the location of a small leak in an underground or buried cable. When a mercury manometer or C pressure gauge is employed and accuracy to the nearest 0.01 psi is required, altitude correction should be applied for differences in elevation of 20 feet or more. Pressure measurements made with a W. and T. manometer, which provides accurate measurements to ±0.001 psi, should be corrected for differences of 1 foot or more in elevation.
- 4.16 No altitude correction is necessary when checking or adjusting the operating pressures of contactors. All contactors are set to operate at a fixed pressure above atmospheric pressure, regardless of altitude. However, it should be

recognized that the cable pressure will be less at the higher elevations of a cable section.

- 4.17 Altitude correction is necessary when the pressure measurement(s) at one elevation are to be compared with a measurement(s) at a different elevation.
- 4.18 Ordinary Corrections: Pressure measurements made at different elevations may be converted to their equivalent values at a common elevation by the use of Table C.
- 4.19 The altitude correction always should be based on the difference in elevation between the valve point where the pressure is measured and the elevation of the lowest valve point in the section of cable under test. The altitude correction is added to the pressure readings taken at valves above the base elevation to obtain the equivalent pressure at the base elevation. The reverse is true when determining the correct charging pressure to use at a charging valve above the base elevation of a section. In the latter case, the altitude correction is subtracted from the nominal charging pressure in order to obtain the proper regulator setting at that valve.
- 4.20 The values of altitude correction given in Table C are based on cable pressure at 60°F and normal sea-level atmospheric pressure of 15.0 psi. The corrections will differ slightly at other cable temperatures and atmospheric pressures. For all practical purposes, the cable pressures given in Table C may be considered to be the measured cable pressures, regardless of cable temperature or atmospheric pressure.
- 4.21 Example: Assume that a small leak exists in a section of cable and that appreciable differences in altitude exist between the valve points which must be read to secure a gradient.
  - (1) Prepare a table similar to Table D, and enter in columns 1, 2, and 3 the valve number, pressure at valve, and elevation of each valve, respectively.
  - (2) Enter in column 4 the difference in elevation between the valves and the base elevation. (For convenience, valve number 6 was selected, since it has the lowest elevation—1590 feet.)

TABLE C

-2412-44-5		ADD TO P	RESSURE N	MEASUREL	AT HIGH	EN VALVE	POINT			nit-
DIFFERENCE IN ALTITUDE					CABLE PR	ESSURE (P	SI)			
(FEET)	1	2	3	4	5	6	7	8	9	10
20	0	0	0	0	0	0	0	0.01	0.01	0.01
30	0	0	0	0	0	0.01	0.01	0.01	0.01	0.01
40	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01
50	0	0	0	0.01	0.01	0.01	0.01	0.01	0.02	0.02
60	0	0	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
70	0	0	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
80	0	0	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03
90	0	0	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.03
100	0	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.08
200	0	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.06	0.07
300	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
400	0.01	0.02	0.04	0.05	0.06	0.08	0.09	0.10	0.12	0.13
500	0.01	0.03	0.04	0.06	0.08	0.10	0.11	0.13	0.15	0.17
600	0.01	0.03	0.05	0.07	0.10	0.12	0.14	0.16	0.18	0.20
700	0.01	0.04	0.06	0.09	0.11	0.14	0.16	0.18	0.21	0.23
800	0.01	0.04	0.07	0.10	0.13	0.15	0.18	0.21	0.24	0.27
900	0.02	0.05	0.08	0.11	0.14	0.17	0.21	0.24	0.27	0.30
1000	0.02	0.05	0.09	0.12	0.16	0.19	0.23	0.26	0.30	0.34

Note: Correction for differences in elevation greater than shown above may be obtained by adding the corrections for two or more of the differences in elevation to obtain the desired total.

- (3) Enter in column 5 the altitude correction obtained from Table C by use of columns 2 and 4 of Table D. For example, the observed pressure at valve 1 is 8.00 psi and the altitude difference from the base is 190 feet. In Table C, the altitude correction for 8.00 psi at 100 feet is 0.03 psi, and at 90 feet, it is 0.02 psi, which gives a total of 0.05 psi. This total (0.05 psi) is entered in column 5 and then added to the observed pressure (column 2) to give a corrected pressure of 8.05 psi, which is entered in column 6. Corrections for the other values are obtained in a similar manner.
- 4.22 When the observed pressure falls between two columns (Table C) and the difference in altitude correction in the two columns is 0.01 psi, use the correction value in the column which is nearest the pressure reading. For example, if the pressure reading is 7.40 psi and the difference in altitude from base is 300 feet, use 0.07 psi as the correction.
- 4.23 When the observed pressure falls between two columns (Table C) and the difference in altitude correction in the two columns is 0.02 psi or greater, it is necessary to interpolate between

TABLE D

VALVE NO.	OBSERVED PRESSURE READING (PSI)	ELEVATION OF INSTRUMENT (FT)	DIFF. IN ALTITUDE FROM BASE* (FT)	ALTITUDE CORRECTION (PSI)	PRESSURE READING (PSI)
COL 1	COL 2	COL 3	COL 4	COL 5	COL 6
1	8.00	1780	190	0.05	8.05
2	7.74	1845	255	0.07	7.81
3	7.48	1775	185	0.04	7.52
4	7.48	1715	125	0.03	7.51
5	7.73	1660	70	0.02	7.75
6	8.05	1590	0		8.05

\*Base Elevation 1590 Feet

the two values to determine the altitude correction. For example, if the observed pressure is 8.50 psi and the difference in altitude from the base elevation is 500 feet, use an altitude correction of 0.14 psi because it is halfway between the values of 0.13 for 8 psi and 0.15 for 9 psi.

- 4.24 Precise Corrections: The elevation corrections for precise measurements given in Table E are for absolute pressure readings of 19.0 to 24.0 psia at cable temperatures of 30° to 101°F. By interpolation, correction values are determined for pressure readings to the closest 0.01 psia. This degree of accuracy will be sufficient for determining the altitude correction to be applied.
- 4.25 Since the correction values in Table E are given in psia-per-foot elevation difference, these values must be multiplied by the difference in elevation before being added to the pressure readings to obtain the equivalent pressure at the base elevation.
- 4.26 Example: Assume that a pressure measurement of 23.128 psia taken at a cable temperature of 65°F is to be corrected for an

elevation difference of 4.7 feet above the base location (lowest valve point):

- (1) The 23.128 psia pressure reading is rounded off to the closest 0.01 psi, which is 23.13 psia.
- (2) For a cable temperature of 65°F, Table E shows a correction value of 0.000799 psi for a pressure of 23.1 psia, and 0.000802 psi for a pressure of 23.2 psia.
- (3) The correction value for the 23.13 psia is approximately one-third the difference of 0.000003, or 0.000001. Adding to 0.000799, we get 0.0008.
- (4) The 0.0008 then is multiplied by the elevation difference of 4.7 feet to obtain the total correction.

 $0.0008 \times 4.7 = 0.00376$  or 0.004 psi.

(5) Add the 0.004 psi correction to the 23.128 psia measurement to obtain the equivalent pressure at the base elevation.

23.128 + 0.004 = 23.132 psia (corrected absolute pressure measurement).

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												-										
P S I A	30° 31°	- 1	34°		- 1	38° 39°	400	110 420	430 440	45°	Cable Temperature	4 Rº 4	90 500	510 520	6.30	5.4° 5.5°	460 8	57° 58°	50° 60°	8 10	20 6 30	64° 6
0.6	2000104 000702	000101 000	000698	000 697 000	10000	000	069000	0	0	000083	0	000019	878	0	000672	-		1.	199	3 00062	199	
18.5		108	707 705	104	101				693 6				685 683	9 289	679	678	675	674 673	0	699	999	99
	715	118		108	710 708		702 701	103 698	9692	202	69 69	069		9 9 9	683	681	6 19	678 676	675	74 672	671 670	669
19.5		719		115	112				104	101 20	669	697	695 694	693	069	689	989	685 683	682 6	619	678	675
9 6		123		119					101	104	703 702	2 100	699	9 9 9 9	888 883	169 269	689	- 89	685	683	681 680	679
		121		222		1	1	2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		80	101	900		100	169	969	693	269	689		685 684	682
	137 136	134	733 731	730		125 12		121 120	111	11.5	911		110	101	200	200	900	695	200	0 0 0	200	9 6 8 9
20 0		738		133				125 723	122	20 719	717	115	713 712	110	108	106 105	703	102 101	9 669		695 694	693
102	145 74	141	740 738	131	135 734	133 73		128 127	125	24 122	121 121	817	717 715	114	13 711	710 708	101	106 704	103		688	989
2 0 2	1	200						261	621	921	125 12	122	120	718	91.	713 712	0	109	901			000
20.4		753		748		I		139 738	736	15 713	21 611	198	361 161	361	201	100		115	011	101	900	200
20.5		156		152				143 741	740	38 737	135 134	132	131 730	128	17 125	724 122	121	720 718	111	311		01
9 02	163 162	160	158 151	155		151	8 7 6	746 745	143	42 740	739 73	136	135 733	132 7	30 729	127 126	125	123 122	120	912	716 715	• 1.
20 1		164		159				0	141	45 744	743 74	140	138 137	135 7	34 732	731 729	128	127 125	124 1	22 721	720 718	111
8 0 6	69.	167	766 764	163	0 2 2	90	90	157	000	6.5	146	2 4 3	142 740	739 7	37 736	734 733	132	750 729	181	725	123 122	121
0 12		115		110				161 759	151	56 755	153	150	749 747	146	141	749 740	1 100	111		631	1 10	191
1 12	182 780	178		114	112 111	769		764 763	191	80 7 58	157 753	154	752 751	149		745	742	741	738	36 735	134 132	131
2 1 2	785 78	182		111			71 770		765	63 762	760 755	151	756 755	153	52 750	749 747	146	144 743	141	40 739	137 736	134
	800	900		181		I		211	60.	990	9	191	760 758	157	55 754	152 751	149	148 746	2			138
2		193		788				111	116	11	171	2 4 2	281 131	764	101	156	133	150	163	0 77	148	145
		191		192				183 181	17.9	31.1	115 11	3 112	770 769	167 74	191	763 761	160	158 157	155	54 753	151 150	148
-	804 802	801	199 197	196	194 192	-	89 7 98	786 785	183	780	77.8 17.	175	114 112	111 1	89 768	766 765	163	762 760	7.59	57 756	155 753	152
				200		200	I	000		200	201	0	911	174	13 171	770 768	767	765 764	162	0 :	158 756	155
2 0		812		108		I		187	181	181	286	786	785 783	781	27.0	110	0 4 4	119	160	188	765 761	78.7
1.2		818	814 812		108 608	908		861 198	181	161 96	193 191	180	788 787	785 7	13 782	780 779	111	176 174	113	110	168	166
2 2 4	822 821	6 .		•	812 811	808	908	804 803	100	98 188	196	193	192 790	789 7	185	784 782	181	179 778	1 911	113	172 176	169
6 22		628			9 6			Ï	500	0.0	000	181	195 794	192 1	682	187	184	103 701	000	111	175 774	112
2.5	833 832	0.8	828 827					818	0 0 0	000	208	200		980	100		8 0	900	183	200	180	
9 2	837 83	934		828	821 825	824 82		6.8	818	14 812	118	807	808	803	900	198	195	191	1 90	787	786 784	183
1.2.1		188	36 834	832		•	26 824	822 821	6 - 9	918		118	808 808	808 81	15 803	802 800	198	197 195	184	181 26	189 188	98.
9 2		-		836	834 833	831		826 824	623 6	619	918	51.0	813 811	810 8	708 807	808 803	802	861 108	181	184	193 791	190
6 3 6		2	210		T	000		020	920	628 62	128 128	8 6	812	813	019	809	808	804 802	100	198	196	193
3 -	856 854	852	21 848		848	842	8 3 9	837 835	833	32 830	829 821	828	824 822	821	0 0	218	808	900	808	808	801 802	008
3.5		856	854 852				•	841 839	837 8	35 834	632 631	828	827 826	824 8	128 24	6.0	918	815 813		10 808	802	100
23.3		090			188	618	9 6	844		39 837	8 36 8 3	633	831 829	828 8	10 824	823 821	8 8	9	818	13 812	808	200
-		663				I	130	0 0			628	969	834 833	9 3	929	826 825	823	822 820		618	210	
23.6		11.8	69			860	8 5 7		851	50 848	847 845		842 840	0 80	635	833 837	9 2 9	829 827	8 2 2 8	24 822	421	
13.1	878 878	118	873 871	869	998 198	864 862	980	859 857	655	53 852	850 848		845 843	8 42 8	839	837 635	18	832 830	8 29 8	27 826	824 822	128
0 62	200			200	698		9 .	862 861	828	57 855	854 852	8 2 0	648	845 8	2 9 4 5	840 838	837	836 834	8 32 8	31 829	828 828	924
									4621	054												

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TABL	E	E	(Cont)

Absolute									PRESSUF	E CORREC	TION PER	FT CHAM	IGE IN E	LEVATIO	V											and the same
Pressure											ble Temper						1									
PSIA		69° 70°			74° 75		77° 78°	7 9°	80°		2° 83°		85°		87° 88					93°		95° 96			99° 1	
190	659 658 657	655 654				45 000643 0	646 64		000639	641	640 63	.0006	4 .00063	635	634 6	33 63		959000, 15	.000625	000624	626			2 621		619 614
19.2	663 661 660	659 658		55 654		51 650	649 64		645	644	643 64	2 6	631	638		36 63		632	631	630	629			6 625		622 621
19.3	666 665 664	662 661		59 657		55 653	652 65	1 650	649	648	646 64	5 6	4 64	642	640 6	39 63	8 63	17 636	635	633	632	631	630 62			626 624
194	669 668 667	666 664	663 6	62 661		58 657	656 65			651	650 64	9 64				43 64			638	637	636		633 63			629 628
19.5	673 672 670	669 668		664		62 660 65 664	659 65		655	654	653 65	2 6	1 645			46 64			641	640	639	638	636 63 640 63	6 634		632 631
19.6	616 615 614 680 678 677	672 671		69 667		65 664	666 66			658	660 65	5 6	1 65	652	650 6 654 6	52 65			644	643	642		643 64			635 634
19.8	683 682 681	679 678		16 674	673 6	12 670	669 66	8 667	665	664	663 66	2 61	1 651	658		56 65			651	650	649		646 64			642 641
19.9	687 685 684	683 682		19 678		15 674	673 67		669	668	666 66		4 66		660 6				654	653	652		650 64			645 644
20.0	690 689 688	686 685				19 677	676 61		672	671	670 66		7 666			62 66			658	656	655		653 65			648 647
201	694 692 691	690 688				82 681 85 684	619 61	8 677	676	674	673 67		661	668	667 6	66 66		3 662 1 665	661	660	658	657	656 65 659 65	8 657	656	651 650
20.2	701 696 694	693 692		89 688		89 687	686 68		682	681	680 67		1 67	675	674 6				667	666	665		663 66			658 657
20 4	704 703 701	700 699		96 695		92 691	690 68			684	683 68		675			16 67		3 672	671	670	668		66 66			661 660
20.5	707 706 705	103 702	701 6	99 698	697 6	96 694	693 69				687 68		4 68		680 6				674	673	672		669 66			664 663
20.6	711 709 708	707 706		03 701		99 698	696 69			691	690 68		686	685		82 68			681	676	675	674	672 67		669	668 666
20 7	714 713 712	710 709		10 708		02 701	700 69			694	693 69		681	688		89 68			684	679	678		676 67 679 67			671 670
20.9	721 720 719	717 716		13 712		09 708	706 70			701	700 69		7 696	695		92 69			687	686	685		682 68			677 676
21 0	725 723 722	721 719	718 7	17 715	714 7	13 711	710 70	9 707	706	705	703 70	2 10	1 691		697 6	96 69	4 69	3 692	690	689	688	687	885 68	4 683	682	681 679
21 1	728 727 725	124 123		20 718		16 714	713 71			708	707 70		14 70			99 69			694	693	691		689 68			684 683
21 2	732 730 729	121 126		23 122		19 718	717 71	5 714	713	711	710 70	9 70	7 706		703 1	02 10			697 700	696	695		92 69 595 69			687 686
21.3	735 734 732	731 730		10 129	124	23 721	123 12	2 721	716	718	717 71	2 7	14 71		710 7				704	702	701		598 69			690 689
21.5	742 740 739	738 736		14 732		29 728	727 12			721	720 71		7 716		713 7				707	706	704		102 70			697 696
21.6	745 744 743	741 740	738 7	37 735		33 731	130 72			125	723 72	2 7:	715	718		15 71	4 71	3 712	710	709	108	706	105 10	4 703		700 699
21:1	149 147 146	745 743		10 739		36 135	133 13	2 731		728	727 72		14 72	721	720 1	19 71			713	712	711		708 70		105	103 102
2128	752 751 749 756 754 753	748 747		14 742		40 738	737 73	6 734 9 737		731	730 72		1 721	6 725 9 728	123 1	22 12			717	715	714	713	712 71		708	710 708
22.0	759 758 756	755 754		749		46 745		2 741		138	737 73		14 73			29 12			723	722	721	719	718 71		714	713 712
22.1	763 761 760	758 757		54 753		50 748	747 74			741	T40 T3		1 136	735	733 7	32 73	1 72	9 728	721	725	124	123	721 72			T16 715
22.2	766 765 763	762 760		1 156	755 1	53 752	750 74	9 747	746	745	143 14	2 7	1 731	738	737 7	35 73		3 731	730	129	121	126	725 12	3 722	121	720 718
223	770 168 161	165 164		1 759		57 755	754 75	2 751		748	147 14		14 74		140 1				133	132	731	129	128 12		124	123 121
22.4	775 771 770	169 161		163		60 758	757 TS	9 754		752	750 74		741		743 7	42 14			737	735	734	732		3 732	727	126 125
22.6	180 178 177	115 174		11 170		67 765	764 76			758	151 15		4 75			49 74			743	74.2	740	739	138 13		734	732 731
22.1	783 782 780	179 777		15 173		10 769	167 76			762	160 75		756						746	745	744			0 738	131	736 734
22.8	787 785 784	182 181	119 1	18 116		14 172	171 76	9 768		765	764 76	2 71	1 751		757 1			2 751	750	148	747			3 742	740	738 738
22.9	790 789 787	186 184		1 780		17 115	174 11			768	161 16		4 16			58 15			753	152	750			6 745	144	142 141 145 144
23.0	797 796 794	789 788		85 783		80 779	781 77	9 774		172	770 76		761		163 1	62 76			756	755	753	152	751 75		750	145 144
23.2	801 799 798	796 795		92 790	789 7	87 786	784 78	3 781		778	111 11		4 77	1 771	770 7	68 76		16 764	763	761	760	759		6 755	753	752 751
23.3	804 802 801	799 798		95 793	192 1	91 789	788 78	6 185	783	782	180 11		11 116	114	113 1				766	165	763	162		9 758	757	155 154
23.4	808 806 804	803 801		98 797		94 192	791 78			785	784 78		11 171						769	168				3 761		758 757
23.5	811 809 808	806 805		02 800		97 796 01 799	794 T9			788	181 18		14 78	3 781		78 17	7 71	16 174	113	171	770	76 8 772		6 764	763	162 760
23.6	814 813 811	810 808 813 812		05 804		04 802	798 79 801 80			792	790 78		781	784	783 7	85 78	4 74	19 781	776	175	776	112	174 11		770	768 767
23.8	821 820 818	817 815	813 8	12 810		08 806	804 80		800	198	797 79		14 79	791		88 78		5 784	783	781	780	778		6 774		771 776
23.9	825 823 822	820 819	817 8	15 814	812 8	11 809	808 80	6 805	803	802	800 79	9 71	796	194		92 791			786	184	183	782		9 777	716	115 113
24.0	000828 000827 000825	000823 000822	000 820 0008	19 000817 00	0816 0008	14 000813 0	00811 00081	0 000808	000807	000805 00	804 00080	2 ,000 8	000799	861000.	1000, 361000.	95 .00079	3 ,00075	187000,5	,000789	000788	000786	000785 000	783 00078	2 .000781	000779 0	317000 81100