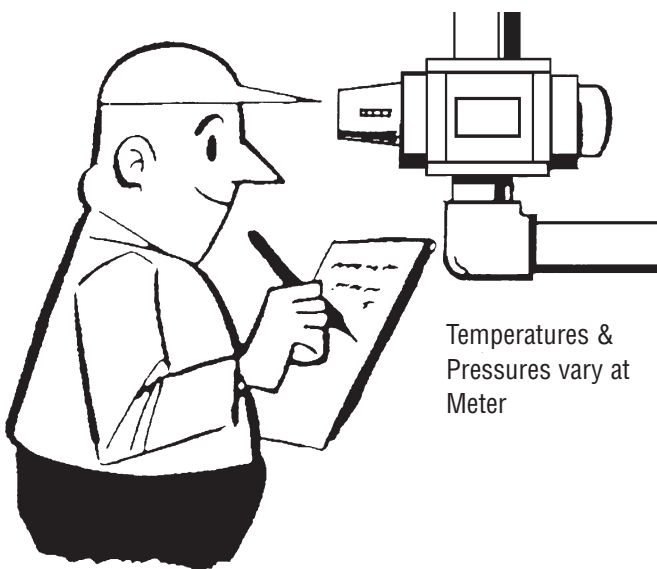


## The Application of Temperature and/or Pressure Correction Factors in Gas Measurement

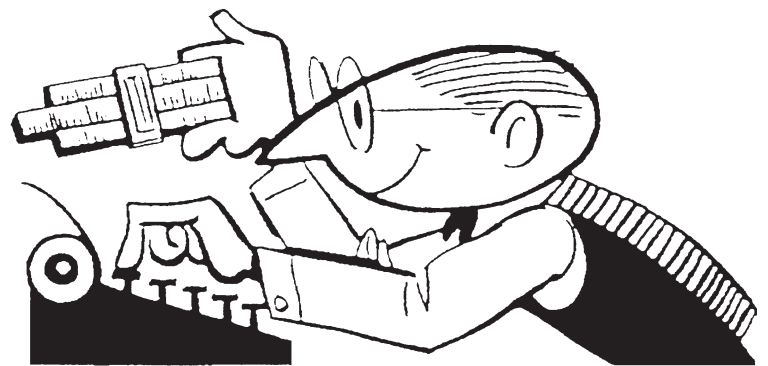
COMBINED BOYLE'S – CHARLES' GAS LAWS

To convert measured volume at metered pressure and temperature to selling volume at agreed base pressure and temperature

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$



Temperatures & Pressures vary at Meter



Readings must be converted to Standard conditions for billing

## Application of Correction Factors for Pressure and/or Temperature

### Introduction

Most gas meters measure the volume of gas at existing line conditions of pressure and temperature. This volume is usually referred to as displaced volume or actual volume ( $V_A$ ). The value of the gas (i.e., heat content) is referred to in gas measurement as the standard volume ( $V_S$ ) or volume at standard conditions of pressure and temperature.

Since gases are compressible fluids, a meter that is measuring gas at two (2) atmospheres will have twice the capacity that it would have if the gas is being measured at one (1) atmosphere. **(NOTE: One atmosphere is the pressure exerted by the air around us. This value is normally 14.696 psi absolute pressure at sea level, or 29.92 inches of mercury).**

This fact is referred to as Boyle's Law which states, "Under constant temperature conditions, the volume of gas is inversely proportional to the ratio of the change in absolute pressures". This can be expressed mathematically as:

$$P_1 V_1 = P_2 V_2 \quad \text{or} \quad \frac{P_1}{P_2} = \frac{V_2}{V_1}$$

Charles' Law states that, "Under constant pressure conditions, the volume of gas is directly proportional to the ratio of the change in absolute temperature". Or mathematically,

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{or} \quad V_1 T_2 = V_2 T_1$$

Gas meters are normally rated in terms of displaced cubic feet per hour. For gas equipment rated in B.T.U.'s, a simple conversion can be applied to the B.T.U./Hr. Rating to obtain SCFH (Standard Cubic Feet per Hour). The table below lists the most commonly used gases and their approximate conversion factors.

| Gas         | Heating Value<br>B.T.U.'s/Cu. Ft. | To Obtain SCF, Multiply B.T.U.<br>Ratings of Equipment by |
|-------------|-----------------------------------|---|
| Butane      | 3333                              | .00030  |
| Ethane      | 1758                              | .00056  |
| Methane     | 997                               | .00100  |
| Natural Gas | 965 to 1055                       | .00100  |
| Propane     | 2529                              | .00040  |

\* See Appendix A for combined formula and application.

The displaced capacity of the meter can be found on the meter nameplate or in the model designation where the “C” represents a multiplier of one hundred (100) and “M” represents a multiplier of one thousand (1000). For example, a 3M175 meter has a displaced volume capacity of 3000 ACFH.

The “175” is the maximum working pressure in pounds per square inch gauge pressure (psig). If a 3M175 meter is installed on a 15 psig system (or 2 atmospheres), the meter will have a standard volume capacity of 6000 SCFH. This is true since the gas at two (2) atmospheres is compressed to one-half of its displaced volume or volume at standard conditions. The gas meter, however, will only measure the displaced volume and the counter on the meter will only register 3000 cubic feet in a one hour period (assuming gas flow is at the meter’s maximum capacity).

For these reasons the counter reading or actual volume ( $V_A$ ) must be corrected to standard volume ( $V_S$ ) to obtain the real value of the gas that has passed through the meter.

Engineering Data Sheet RM-26 has a listing of gas pressure and temperature correcting factors. To determine the standard volume for a given period of time, simply subtract the initial counter reading from the final counter reading and multiply this difference by the appropriate factor for pressure ( $F_P$ ) and, if desired, by the appropriate factor for temperature ( $F_T$ ). There is an approximate 1% change in volume for every 5°F.

**NOTE: If the gas meter being utilized is already temperature compensated (TC), then the temperature correcting factor should not be used.**

**Example:** A 3M175 Counter Version ROOTS® Meter is installed inside on a 25 psig gas line. Calculate the standard volume of gas (corrected for both pressure and temperature) if the gas temperature is 75°F.

$$V_S = V_A \times F_P \times F_T$$

| Period | Meter Counter Readings |         |                      | $F_P$ *@<br>25 psig | Volume Corrected<br>for Pressure | $F_T$ *@<br>75°F* | Volume<br>Corrected for<br>Press. & Temp. |
|--------|------------------------|---------|----------------------|---------------------|----------------------------------|-------------------|---|
|        | Final                  | Initial | Difference ( $V_A$ ) |                     |                                  |                   |   |
| 1      | 008200                 | 000000  | 8200                 | 2.675               | 21935                            | 0.972             | 21321                                     |
| 2      | 017900                 | 008200  | 9700                 | 2.675               | 25948                            | 0.972             | 25221                                     |
| 3      | 028400                 | 017900  | 10500                | 2.675               | 28088                            | 0.972             | 27301                                     |
| 4      | 031600                 | 028400  | 3200                 | 2.675               | 8560                             | 0.972             | 8320                                      |

\* See Data Sheet RM-26 for values.

If the temperature or pressure changes from one period to another, the factor for pressure ( $F_P$ ) or temperature ( $F_T$ ) can be adjusted before calculating the standard volume.

The values on the Data Sheet, RM-26, are for a base pressure of 14.73 psia, an assumed atmospheric pressure for 14.40 psia (or about 500 ft. above sea level elevation), and a base temperature of 60°F. For other base conditions, the formulae for calculating the factors for pressure and temperature are given below:

$$F_P = \frac{\text{Line Pressure (psig)} + \text{Atmospheric Pressure (psia)}}{\text{Contract Base Pressure (psia)}}$$

$$F_T = \frac{460 + \text{Base Temperature (°F)}}{460 + \text{Line Temperature (°F)}}$$

**NOTE: The Base Pressure and Base Temperature values can normally be found in your contract with your gas supplier. The atmospheric pressure can be assumed based upon your elevation above sea level or by contacting your local weather station or airport facility. (See table below).**

### Atmospheric Pressures and Barometer Reading at Different Altitudes

| Altitude Above Sea Level Feet | Atmospheric Pressure psia | Barometer Reading Inches Hg | Altitude Above Sea Level Feet | Atmospheric Pressure psia | Barometer Reading Inches Hg |
|-------------------------------|---------------------------|-----------------------------|-------------------------------|---------------------------|-----------------------------|
| Sea Level                     | 14.69                     | 29.92                       | 4,000                         | 12.68                     | 25.84                       |
| 250                           | 14.56                     | 29.64                       | 4,500                         | 12.45                     | 25.36                       |
| 500                           | 14.42                     | 29.38                       | 5,000                         | 12.22                     | 24.89                       |
| 750                           | 14.29                     | 29.09                       | 6,000                         | 11.77                     | 23.98                       |
| 1,000                         | 14.16                     | 28.86                       | 7,000                         | 11.33                     | 23.09                       |
| 1,250                         | 14.04                     | 28.59                       | 8,000                         | 10.91                     | 22.22                       |
| 1,500                         | 13.91                     | 28.33                       | 9,000                         | 10.50                     | 21.38                       |
| 1,750                         | 13.79                     | 28.08                       | 10,000                        | 10.10                     | 20.58                       |
| 2,000                         | 13.66                     | 27.82                       | 11,000                        | 9.71                      | 19.75                       |
| 2,500                         | 13.41                     | 27.31                       | 12,000                        | 9.34                      | 19.03                       |
| 3,000                         | 13.16                     | 26.81                       | 13,000                        | 8.97                      | 18.29                       |
| 3,500                         | 12.92                     | 26.32                       | 14,000                        | 8.62                      | 17.57                       |

## Gas Pressure Correcting Factors

Base Pressure = 14.73 psia

Atmospheric Pressure = 14.4 psia

Factors listed are directly usable to convert volume readings from displacement meters at various metering pressures into volumes at the standard base pressure and atmospheric pressure indicated above. For a 14.65 base pressure, use an additional multiplier of 1.006.

| PSIG | Factor | PSIG | Factor | PSIG | Factor | PSIG | Factor | PSIG | Factor | PSIG | Factor |
|------|--------|------|--------|------|--------|------|--------|------|--------|------|--------|
| 1    | 1.045  | 61   | 5.119  | 121  | 9.192  | 405  | 28.47  | 705  | 48.84  | 1005 | 69.20  |
| 2    | 1.113  | 62   | 5.187  | 122  | 9.260  | 410  | 28.81  | 710  | 49.18  | 1010 | 69.54  |
| 3    | 1.181  | 63   | 5.254  | 123  | 9.328  | 415  | 29.15  | 715  | 49.52  | 1015 | 69.88  |
| 4    | 1.249  | 64   | 5.322  | 124  | 9.396  | 420  | 29.49  | 720  | 49.86  | 1020 | 70.22  |
| 5    | 1.317  | 65   | 5.390  | 125  | 9.464  | 425  | 29.83  | 725  | 50.20  | 1025 | 70.56  |
| 6    | 1.385  | 66   | 5.458  | 130  | 9.803  | 430  | 30.17  | 730  | 50.54  | 1030 | 70.90  |
| 7    | 1.453  | 67   | 5.526  | 135  | 10.142 | 435  | 30.51  | 735  | 50.86  | 1035 | 71.24  |
| 8    | 1.521  | 68   | 5.594  | 140  | 10.482 | 440  | 30.85  | 740  | 51.22  | 1040 | 71.58  |
| 9    | 1.589  | 69   | 5.662  | 145  | 10.821 | 445  | 31.19  | 745  | 51.55  | 1045 | 71.92  |
| 10   | 1.656  | 70   | 5.730  | 150  | 11.161 | 450  | 31.53  | 750  | 51.89  | 1050 | 72.26  |
| 11   | 1.724  | 71   | 5.798  | 155  | 11.50  | 455  | 31.87  | 755  | 52.23  | 1055 | 72.60  |
| 12   | 1.792  | 72   | 5.866  | 160  | 11.84  | 460  | 32.21  | 760  | 52.57  | 1060 | 72.94  |
| 13   | 1.860  | 73   | 5.933  | 165  | 12.18  | 465  | 32.54  | 765  | 52.91  | 1065 | 73.28  |
| 14   | 1.928  | 74   | 6.001  | 170  | 12.52  | 470  | 32.88  | 770  | 53.25  | 1070 | 73.62  |
| 15   | 1.996  | 75   | 6.069  | 175  | 12.86  | 475  | 33.22  | 775  | 53.59  | 1075 | 73.96  |
| 16   | 2.064  | 76   | 6.137  | 180  | 13.20  | 480  | 33.56  | 780  | 53.93  | 1080 | 74.30  |
| 17   | 2.132  | 77   | 6.205  | 185  | 13.54  | 485  | 33.90  | 785  | 54.27  | 1085 | 74.64  |
| 18   | 2.200  | 78   | 6.273  | 190  | 13.88  | 490  | 34.24  | 790  | 54.61  | 1090 | 74.98  |
| 19   | 2.267  | 79   | 6.341  | 195  | 14.22  | 495  | 34.58  | 795  | 54.95  | 1095 | 75.32  |
| 20   | 2.335  | 80   | 6.409  | 200  | 14.55  | 500  | 34.92  | 800  | 55.29  | 1100 | 75.66  |
| 21   | 2.403  | 81   | 6.476  | 205  | 14.89  | 505  | 35.26  | 805  | 55.63  | 1105 | 75.99  |
| 22   | 2.471  | 82   | 6.544  | 210  | 15.23  | 510  | 35.60  | 810  | 55.97  | 1110 | 76.33  |
| 23   | 2.539  | 83   | 6.612  | 215  | 15.57  | 515  | 35.94  | 815  | 56.31  | 1115 | 76.67  |
| 24   | 2.607  | 84   | 6.680  | 220  | 15.91  | 520  | 36.28  | 820  | 56.65  | 1120 | 77.01  |
| 25   | 2.675  | 85   | 6.748  | 225  | 16.25  | 525  | 36.62  | 825  | 56.98  | 1125 | 77.35  |
| 26   | 2.743  | 86   | 6.816  | 230  | 16.59  | 530  | 36.96  | 830  | 57.32  | 1130 | 77.69  |
| 27   | 2.810  | 87   | 6.884  | 235  | 16.93  | 535  | 37.30  | 835  | 57.66  | 1135 | 78.03  |
| 28   | 2.878  | 88   | 6.952  | 240  | 17.27  | 540  | 37.64  | 840  | 58.00  | 1140 | 78.37  |
| 29   | 2.946  | 89   | 7.020  | 245  | 17.61  | 545  | 37.98  | 845  | 58.34  | 1145 | 78.71  |
| 30   | 3.014  | 90   | 7.088  | 250  | 17.95  | 550  | 38.32  | 850  | 58.68  | 1150 | 79.05  |
| 31   | 3.082  | 91   | 7.155  | 255  | 18.29  | 555  | 38.66  | 855  | 59.02  | 1155 | 79.39  |
| 32   | 3.150  | 92   | 7.223  | 260  | 18.63  | 560  | 39.00  | 860  | 59.36  | 1160 | 79.73  |
| 33   | 3.218  | 93   | 7.291  | 265  | 18.97  | 565  | 39.33  | 865  | 59.70  | 1165 | 80.07  |
| 34   | 3.286  | 94   | 7.359  | 270  | 19.31  | 570  | 39.67  | 870  | 60.04  | 1170 | 80.41  |
| 35   | 3.354  | 95   | 7.427  | 275  | 19.65  | 575  | 40.01  | 875  | 60.38  | 1175 | 80.75  |
| 36   | 3.422  | 96   | 7.495  | 280  | 19.99  | 580  | 40.35  | 880  | 60.72  | 1180 | 81.09  |
| 37   | 3.489  | 97   | 7.563  | 285  | 20.32  | 585  | 40.69  | 885  | 61.06  | 1185 | 81.42  |
| 38   | 3.557  | 98   | 7.631  | 290  | 20.66  | 590  | 41.03  | 890  | 61.40  | 1190 | 81.76  |
| 39   | 3.625  | 99   | 7.698  | 295  | 21.00  | 595  | 41.37  | 895  | 61.74  | 1195 | 82.10  |
| 40   | 3.693  | 100  | 7.766  | 300  | 21.34  | 600  | 41.71  | 900  | 62.08  | 1200 | 82.44  |
| 41   | 3.761  | 101  | 7.834  | 305  | 21.68  | 605  | 42.05  | 905  | 62.42  | 1210 | 83.12  |
| 42   | 3.829  | 102  | 7.902  | 310  | 22.02  | 610  | 42.39  | 910  | 62.76  | 1220 | 83.80  |
| 43   | 3.897  | 103  | 7.970  | 315  | 22.36  | 615  | 42.73  | 915  | 63.10  | 1230 | 84.48  |
| 44   | 3.965  | 104  | 8.038  | 320  | 22.70  | 620  | 43.07  | 920  | 63.44  | 1240 | 85.16  |
| 45   | 4.032  | 105  | 8.106  | 325  | 23.04  | 625  | 43.41  | 925  | 63.77  | 1250 | 85.84  |
| 46   | 4.100  | 106  | 8.174  | 330  | 23.38  | 630  | 43.75  | 930  | 64.11  | 1260 | 86.52  |
| 47   | 4.168  | 107  | 8.242  | 335  | 23.72  | 635  | 44.09  | 935  | 64.45  | 1270 | 87.20  |
| 48   | 4.236  | 108  | 8.310  | 340  | 24.06  | 640  | 44.43  | 940  | 64.79  | 1280 | 87.88  |
| 49   | 4.304  | 109  | 8.377  | 345  | 24.40  | 645  | 44.76  | 945  | 65.13  | 1290 | 88.55  |
| 50   | 4.372  | 110  | 8.445  | 350  | 24.74  | 650  | 45.10  | 950  | 65.47  | 1300 | 89.23  |
| 51   | 4.440  | 111  | 8.513  | 355  | 25.08  | 655  | 45.44  | 955  | 65.81  | 1310 | 89.91  |
| 52   | 4.507  | 112  | 8.581  | 360  | 25.42  | 660  | 45.78  | 960  | 66.15  | 1320 | 90.59  |
| 53   | 4.576  | 113  | 8.649  | 365  | 25.76  | 665  | 46.12  | 965  | 66.49  | 1330 | 91.27  |
| 54   | 4.644  | 114  | 8.717  | 370  | 26.10  | 670  | 46.46  | 970  | 66.83  | 1340 | 91.95  |
| 55   | 4.711  | 115  | 8.785  | 375  | 26.44  | 675  | 46.80  | 975  | 67.17  | 1350 | 92.63  |
| 56   | 4.779  | 116  | 8.853  | 380  | 26.78  | 680  | 47.14  | 980  | 67.51  | 1360 | 93.31  |
| 57   | 4.847  | 117  | 8.920  | 385  | 27.11  | 685  | 47.48  | 985  | 67.85  | 1380 | 94.66  |
| 58   | 4.915  | 118  | 8.988  | 390  | 27.45  | 690  | 47.82  | 990  | 68.19  | 1400 | 96.02  |
| 59   | 4.983  | 119  | 9.056  | 395  | 27.79  | 695  | 48.16  | 995  | 68.53  | 1420 | 97.38  |
| 60   | 5.051  | 120  | 9.124  | 400  | 28.13  | 700  | 48.50  | 1000 | 68.87  | 1440 | 98.74  |

## Gas Temperature Correcting Factors

Factors listed are usable to convert gas volume readings from displacement meters at various temperatures to volumes at the standard base temperature of 60°F.

| °F  | Factor | °F | Factor | °F | Factor | °F  | Factor |
|-----|--------|----|--------|----|--------|-----|--------|
| -20 | 1.1818 | 20 | 1.0833 | 60 | 1.0000 | 100 | 0.9286 |
| -19 | 1.1791 | 21 | 1.0811 | 61 | 0.9981 | 101 | 0.9269 |
| -18 | 1.1765 | 22 | 1.0788 | 62 | 0.9962 | 102 | 0.9253 |
| -17 | 1.1738 | 23 | 1.0766 | 63 | 0.9943 | 103 | 0.9236 |
| -16 | 1.1712 | 24 | 1.0744 | 64 | 0.9924 | 104 | 0.9220 |
| -15 | 1.1685 | 25 | 1.0722 | 65 | 0.9905 | 105 | 0.9204 |
| -14 | 1.1659 | 26 | 1.0700 | 66 | 0.9886 | 106 | 0.9187 |
| -13 | 1.1633 | 27 | 1.0678 | 67 | 0.9867 | 107 | 0.9171 |
| -12 | 1.1607 | 28 | 1.0656 | 68 | 0.9848 | 108 | 0.9155 |
| -11 | 1.1581 | 29 | 1.0634 | 69 | 0.9830 | 109 | 0.9139 |
| -10 | 1.1556 | 30 | 1.0612 | 70 | 0.9811 | 110 | 0.9123 |
| -9  | 1.1530 | 31 | 1.0591 | 71 | 0.9793 | 111 | 0.9107 |
| -8  | 1.1504 | 32 | 1.0569 | 72 | 0.9774 | 112 | 0.9091 |
| -7  | 1.1479 | 33 | 1.0548 | 73 | 0.9756 | 113 | 0.9075 |
| -6  | 1.1454 | 34 | 1.0526 | 74 | 0.9738 | 114 | 0.9059 |
| -5  | 1.1429 | 35 | 1.0505 | 75 | 0.9720 | 115 | 0.9043 |
| -4  | 1.1404 | 36 | 1.0484 | 76 | 0.9701 | 116 | 0.9028 |
| -3  | 1.1379 | 37 | 1.0463 | 77 | 0.9683 | 117 | 0.9012 |
| -2  | 1.1354 | 38 | 1.0442 | 78 | 0.9665 | 118 | 0.8997 |
| -1  | 1.1329 | 39 | 1.0421 | 79 | 0.9647 | 119 | 0.8981 |
| 0   | 1.1304 | 40 | 1.0400 | 80 | 0.9630 | 120 | 0.8966 |
| 1   | 1.1280 | 41 | 1.0379 | 81 | 0.9612 | 121 | 0.8950 |
| 2   | 1.1255 | 42 | 1.0359 | 82 | 0.9594 | 122 | 0.8935 |
| 3   | 1.1231 | 43 | 1.0338 | 83 | 0.9576 | 123 | 0.8919 |
| 4   | 1.1207 | 44 | 1.0317 | 84 | 0.9559 | 124 | 0.8904 |
| 5   | 1.1184 | 45 | 1.0297 | 85 | 0.9541 | 125 | 0.8889 |
| 6   | 1.1159 | 46 | 1.0277 | 86 | 0.9524 | 126 | 0.8874 |
| 7   | 1.1135 | 47 | 1.0256 | 87 | 0.9506 | 127 | 0.8859 |
| 8   | 1.1111 | 48 | 1.0236 | 88 | 0.9489 | 128 | 0.8844 |
| 9   | 1.1087 | 49 | 1.0216 | 89 | 0.9472 | 129 | 0.8829 |
| 10  | 1.1064 | 50 | 1.0196 | 90 | 0.9455 | 130 | 0.8814 |
| 11  | 1.1040 | 51 | 1.0176 | 91 | 0.9437 | 131 | 0.8799 |
| 12  | 1.1017 | 52 | 1.0156 | 92 | 0.9420 | 132 | 0.8784 |
| 13  | 1.0994 | 53 | 1.0136 | 93 | 0.9403 | 133 | 0.8769 |
| 14  | 1.0970 | 54 | 1.0117 | 94 | 0.9386 | 134 | 0.8754 |
| 15  | 1.0947 | 55 | 1.0097 | 95 | 0.9369 | 135 | 0.8739 |
| 16  | 1.0924 | 56 | 1.0077 | 96 | 0.9353 | 136 | 0.8725 |
| 17  | 1.0901 | 57 | 1.0058 | 97 | 0.9336 | 137 | 0.8710 |
| 18  | 1.0879 | 58 | 1.0039 | 98 | 0.9319 | 138 | 0.8696 |
| 19  | 1.0856 | 59 | 1.0019 | 99 | 0.9302 | 139 | 0.8681 |

## APPENDIX A

Combining Boyle's Law and Charles' Law gives the relationship:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

This equation states that the volume of a given mass of gas will vary inversely with the absolute pressure and directly with the absolute temperature. By solving this equation for  $V_2$  (selling volume at agreed base pressure and temperature), the value of the gas can be calculated:

$$V_2 = \frac{P_1 V_1 T_2}{P_2 T_1} \quad \text{or} \quad V_2 = V_1 \times \frac{P_1}{P_2} \times \frac{T_2}{T_1}$$

**Note: Values indicated by subscript "2" are standard conditions. Values indicated by subscript "1" are existing line conditions. All pressures and temperatures must be expressed in terms of absolute.**

For example, find the standard volume (or selling volume) which has passed through a meter given the following information:

$V_2$  = Selling or Standard Cubic Feet Volume (SCF), unknown.

$V_1$  = Final Counter Reading - Initial Counter Reading  
= 1,862,900 - 1,743,600 = 119,300 Actual Cubic Feet (ACF).

$P_1$  = 18 psi Gauge Pressure + 14.4 psi (Average Atmospheric Pressure)  
= 32.40 psi Absolute Pressure.

$T_1$  = 460 + 80 (°F) = 540 Absolute Temperature

$P_2$  = 14.73 psi Absolute Contract Base Pressure

$T_2$  = 460 + 60 (°F) = 520 Contract Base Temperature

$$V_2 = V_1 \times \frac{P_1}{P_2} \times \frac{T_2}{T_1} = 119,300 \times \frac{32.40}{14.73} \times \frac{520}{540}$$

$$V_2 = 119,300 \times 2.2 \times .963 = 252,749 \text{ SCF}$$

**Roots Meters & Instruments  
Dresser, Inc.**

16240 Port Northwest Drive  
Houston, TX 77041

Inside US Ph: 800.521.1114      Fax: 800.335.5224  
Outside US Ph: 832.590.2303      Fax: 832.590.2494

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