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# UNITED STATES
# DEPARTMENT OF THE INTERIOR
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## INTERNAL REPORT

PRESSURE MEASUREMENT WITH RUSKA INSTRUMENT CORPORATION PISTON GAGE,

SERIAL NO. 9274

BY

Ted C. Briggs

BRANCH Fundamental Research

PROJECT NO. 4330

DATE November 1964



AMARILLO, TEXAS

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# PRESSURE MEASUREMENT WITH RUSKA INSTRUMENT CORPORATION PISTON GAGE, SERIAL NO. 9274

by

Ted C. Briggs[1/]

## ABSTRACT

This report contains calibration data for Ruska Instrument Corporation piston gage No. 9274, and test data for Ruska Instrument Corporation differential pressure cell No. 9032. The report contains tables to facilitate calculation of a gage pressure. A sample calculation is included in the report.

## INTRODUCTION

The precise measurement of a pressure with a piston gage requires calibration data for the instrument, corrections for the instrument variables, and corrections for the influence of the surrounding environment upon the measured pressure. This report contains calibration data, tables of correction factors, and equations applicable to Ruska Instrument Corporation piston gage No. 9274. The report is a supplement to the operating instructions for the gage.

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1/ Research Chemist, Helium Research Center, Bureau of Mines, Amarillo, Texas

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Ruska piston gage No. 9274 is presently being used to make precise pressure measurements of gases at high pressures. Measurement of gas pressure with an oil piston gage requires separation of the oil from the gas. This separation is achieved by Ruska Instrument Corporation differential pressure cell, serial No. 9032. The measured pressure is influenced by the characteristics of the differential pressure cell; therefore, calibration data for differential pressure cell No. 9032 is included in the report.

For general discussions of pressure measurement with a piston gage refer to National Bureau of Standards Monograph 65[2/], and Ruska static

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2/ J. L. Cross. "Reduction of Data for Piston Gage Pressure Measurements." National Bureau of Standards Monograph 65, June 17, 1963.

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pressure measurement manual[3/].

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3/ "Static Pressure Measurement Laboratory Manual." Ruska Instrument Corporation, Houston, Texas.

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Pressure Measurement with Piston Gage No. 9274

The general equation for calculation of a gage pressure is equation (1).

$$P = \frac{M_a (1 - \rho_a/\rho_b)\, g_1/g_s}{A_o (1 + bP)[1 + c\,(t - 25)]} \qquad (1)$$

The terms in equation (1) are:

$P$ = gage pressure, psig

$M_a$ = apparent mass, of the load on the piston, in air against brass standards, lbs

$\rho_a$ = density of air, gms/cm$^3$

$\rho_b$ = density of brass, gms/cm$^3$

$g_1$ = numerical value for the acceleration of gravity at the gage location, gals

$g_s$ = numerical value for the standard acceleration of gravity, gals

$A_o$ = effective piston area at 25° C and zero pressure, in$^2$

$b$ = fractional change in the effective piston area due to elastic distortion, psi$^{-1}$

$c$ = coefficient of superficial expansion for the piston and cylinder, °C$^{-1}$

Piston gage No. 9274 was calibrated at the Ruska Instrument Corporation plant on February 22, 1962. The gage was calibrated by comparison against Ruska Instrument Corporation laboratory master gage No. 7544. Ruska gage No. 7544 was tested by the National Bureau of Standards, and the piston area of gage No. 7544 is reported to be correct to one part in 10,000 at 25° C. Calibration data supplied by Ruska Instrument Corporation is recorded in table 1.

The weights for gage No. 9274 are of 303 stainless steel with a density of 7.8 grams/cm$^3$. The apparent mass of the weights in air was determined at the Ruska Instrument Corporation plant on February 27, 1962, by comparison against National Bureau of Standards certified

weights. The piston gage weight calibration data is recorded in table 2. Table 3 is a weight summation table obtained from the data in table 2. The weight summations are obtained by adding the weights in alphabetical sequence.

To convert from pounds mass to pounds force the apparent mass $M_a$ is multiplied by the ratio of the local acceleration of gravity $g_l$ to the standard accelerations of gravity $g_s$. A value of 979.4091 gals[4/] is used for the acceleration of gravity at the piston gage

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4/ B. J. Dalton. "Local Value of Acceleration of Gravity at the Helium Research Center." Memorandum Report No. 43, Helium Research Center, April 1964.

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location. Standard acceleration of gravity is 980.665 gals. The ratio $g_l/g_s$ in equation (1) is 0.9987193.

To simplify the calculation of a measured pressure a table of values of $\frac{M_a\ g_l/g_s}{A_o}$ was compiled. The values are listed in table 4, and are weight summations of table 3 multiplied by the gravity ratio and divided by the zero pressure effective piston area at 25° C.

A correction must be applied for the buoyant effect of air upon the piston gage weights. The buoyancy correction is the factor $(1 - \rho_a/\rho_b)$ in equation (1). The density of air $\rho_a$ is a function of the barometric pressure, the temperature, and the relative humidity; therefore, the density correction can vary for each measured gage pressure. A table of density of dry air as a function of barometric weights. The piston gage weight calibration data is recorded in table 2. Table 3 is a weight summation table obtained from the data in table 2. The weight summations are obtained by adding the weights in alphabetical sequence.

To convert from pounds mass to pounds force the apparent mass $M_a$ is multiplied by the ratio of the local acceleration of gravity $g_l$ to the standard acceleration of gravity $g_s$. A value of 979.6091 gals[6/] is used for the acceleration of gravity at the piston gage

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6/ R. J. Dalton. "Local Value of Acceleration of Gravity at the Helium Research Center." Memorandum Report No. 41, Helium Research Center, April 1964.

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location. Standard acceleration of gravity is 980.665 gals. The ratio $g_l/g_s$ in equation (1) is 0.9989232.

To simplify the calculation of a measured pressure a table of values of $\frac{M_a g_l/g_s}{A_o}$ was compiled. The values are listed in table 4, and are weight summations of table 3 multiplied by the gravity ratio and divided by the zero pressure effective piston area at 25° C.

A correction must be applied for the buoyant effect of air upon the piston gage weights. The buoyancy correction is the factor $(1 - \rho_a/\rho_m)$ in equation (1). The density of air $\rho_a$ is a function of the barometric pressure, the temperature, and the relative humidity; therefore, the density correction can vary for each measured gage pressure. A table of density of dry air as a function of barometric pressure and of temperature was computed from equation (2) reference[5].

$$\rho_a = 1.2932 \frac{T_o}{T} P \left[1 - 0.000602(P - 1) - 0.0000105tP\right] \quad (2)$$

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5/ R. E. Barieau. "The Density of Moist Air from 0° to Near 25° C and Near Atmospheric Pressure." Internal Report No. 36, Helium Research Center, August 1963, page 14.

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The terms in equation (2) are:

$\rho_a$ = density of dry air, gms/liter

$T_o$ = absolute temperature at the ice point

$T$ = absolute temperature

$P$ = pressure, atm

$t$ = temperature, °C

Numerical values of the density of dry air in grams/liter were recorded in table 5. Table 6 is a table of buoyancy correction factors $(1 - \rho_a/\rho_b)$ for dry air computed from the values in table 5 and a density of brass of 8.4 grams/cm$^3$.

Ruska Instrument Corporation piston gage 9274 has a re-entrant type cylinder, and the effective piston area decreases with increasing pressure. A correction must be applied for the change of effective area with pressure. The distortion correction is the term $\frac{1}{1 + bP}$ in equation (1). From table 1 $b = -3.5 \times 10^{-8}$ psi$^{-1}$. Values of $\frac{1}{1 + bP}$ for various pressures are recorded in table 7.

The effective piston area is a function of the gage temperature. The factor $\frac{1}{1 + c\ (t - 25)}$ in equation (1) corrects the gage pressure for piston temperatures other than 25° C. Table 8 is a table of temperature correction factors, $\frac{1}{1 + c\ (t - 25)}$.

The measured pressure must be corrected for the zero shift of the differential pressure indicator with pressure. Ruska Instrument Corporation differential pressure cell and indicator, serial No. 9032, were repaired and recalibrated at the Ruska Instrument Corporation plant in June 1964. The zero shift of indicator No. 9032 is given by equation (3).

$$\Delta P = 1.85 \times 10^{-6} P \qquad (3)$$

The quantity $\Delta P$ is added to the measured gage pressure to give the corrected gage pressure. The units of P and $\Delta P$ in equation (3) are psi. Table 9 is a table of corrections for the zero shift with pressure for differential pressure cell No. 9032.

<u>Oil Head Correction</u>

Consideration must be given to the possibility of a pressure correction due to the force exerted by a column of oil in the measuring system.

Brass blocks, machined in the Machine Shop, were placed under the piston gage to raise the piston gage reference plane level to the level of the diaphragm in the differential pressure cell. At present the level of the diaphragm in the differential pressure cell coincides closely to the level of the reference plane of the piston gage. The oil head correction in the present system arrangement is negligible.

Sample Calculation of a Gage Pressure

Suppose one wishes to measure a gas pressure with piston gage No. 9274. Assume the differential pressure meter indicates the null position when weights A, B, C, D, M, O, P, Q, U, W, X, $\bar{A}$, $\bar{C}$, $\bar{D}$, $\bar{E}$, $\bar{G}$, $\bar{H}$, + Tare are on the piston gage. The nominal pressure on the gage would be 4373.783 + 30 psig. From table 4 obtain a corrected pressure of 4367.8341 + 29.9590 = 4397.7931 psig. It should be noted that to obtain the correct pressure from table 4 the weights must be loaded on the gage in sequence, and the tare pressure must be added separately to the pressure due to other weights on the gage. Assume that the corrected barometer reading was 667.35 mm of mercury, and the room temperature was 24.6° C at the time the piston gage balance was obtained. Interpolate between increments in table 6 and obtain a buoyancy correction factor $(1 - \rho_a/\rho_b)$ of 0.9998761. Multiply the corrected gage pressure 4397.7931 psig by the buoyancy correction factor and obtain the pressure 4397.2482 psig. From table 7 obtain the pressure distortion correction factor $\frac{1}{1 + bP}$ of 1.0001539. Suppose the piston gage temperature was 27.3° C at the time of pressure balance. from table 8 obtain the temperature correction factor $\frac{1}{1 + c(t - 25)}$ of 0.9999609. From table 9 obtain the correction 0.0081 psi to be added to the gage pressure to correct for the zero shift with pressure of differential pressure cell No. 9032. Add the null indicator correction to the gage pressure corrected for air buoyancy, and multiply by the distortion and temperature corrections to obtain the gage pressure 4397.7611 psig. Since the piston gage can be balanced to only the nearest 0.001

psi at best, the final reported gage pressure should be rounded to 4397.761 psig. To obtain the measured pressure in psia the atmospheric pressure must, of course, be added to the gage pressure.

TABLE 1. - Ruska Instrument Corporation calibration data for piston gage No. 9274

| | |
|---|---|
| Range. . . . . . . . . . . . . . . | 30 to 12,140 psi |
| $A_o$ . . . . . . . . . . . . . . . . | 0.0260416 $in^2$ |
| b. . . . . . . . . . . . . . . . . | - 3.5 x $10^{-8}$/psi |
| c. . . . . . . . . . . . . . . . . | 1.7 x $10^{-5}$/°C |
| Piston material. . . . . . . . . | Tungsten Carbide |
| Cylinder material. . . . . . . . | A.I.S.I. Type A6 |
| Type cylinder. . . . . . . . . . | Re-entrant |
| Tare (apparent mass) . . . . . . | 0.78118 lb |
| Resolution*. . . . . . . . . . . | < 5 ppm |
| Leak rate. . . . . . . . . . . . | 0.02 in/min for Teresstic #38 oil |
| Plane of reference . . . . . . . | 0.07 in. below line on sleeve weight |

* Minimum resolution at all calibrating test points

TABLE 2. - Ruska Instrument Corporation weight calibration data for piston gage No. 9274

| Designation | Nominal pressure, psi | Apparent mass against brass $M_a$, lbs |
|---|---|---|
| High tare | 30 | 0.78118 |
| A | 1000 | 26.03950 |
| B | 1000 | 26.03943 |
| C | 1000 | 26.03961 |
| D | 1000 | 26.03954 |
| E | 1000 | 26.03954 |
| F | 1000 | 26.03961 |
| G | 1000 | 26.03961 |
| H | 1000 | 26.03961 |
| I | 1000 | 26.03967 |
| J | 1000 | 26.03956 |
| K | 1000 | 26.03963 |
| L | 500 | 13.01975 |
| M | 200 | 5.20789 |
| N | 200 | 5.20791 |
| O | 100 | 2.60401 |
| P | 50 | 1.30197 |
| Q | 20 | 0.52079 |
| R | 20 | 0.52080 |
| S | 10 | 0.26039 |
| T | 5 | 0.13019 |
| U | 2 | 0.05208 |
| V | 2 | 0.05208 |
| W | 1 | 0.02604 |
| X | 0.5 | 0.01302 |
| $\overline{A}$ | 0.2 | 0.00521 |
| $\overline{A}$ | 0.2 | 0.00521 |
| $\overline{B}$ | 0.1 | 0.00260 |
| $\overline{C}$ | 0.05 | 0.00130 |
| $\overline{D}$ | 0.02 | 0.00052 |
| $\overline{D}$ | 0.02 | 0.00052 |
| $\overline{E}$ | 0.01 | 0.00026 |
| $\overline{F}$ | 0.005 | 0.00013 |
| $\overline{G}$ | 0.002 | 0.00005 |
| $\overline{G}$ | 0.002 | 0.00005 |
| $\overline{H}$ | 0.001 | 0.00003 |
| High range piston | | 0.05776 |
| High range table | | 0.72342 |

TABLE 3. - Weight summation table for piston gage No. 9274

| Nominal pressure, psi | $M_a$, lbs | Nominal pressure, psi | $M_a$, lbs |
|---|---|---|---|
| 12,000 | 312.47487 | | |
| 11,000 | 286.43531 | | |
| 10,000 | 260.39568 | | |
| 9,000 | 234.35612 | 0.9 | 0.02344 |
| 8,000 | 208.31645 | 0.8 | 0.02083 |
| 7,000 | 182.27684 | 0.7 | 0.01823 |
| 6,000 | 156.23723 | 0.6 | 0.01562 |
| 5,000 | 130.19762 | 0.5 | 0.01302 |
| 4,000 | 104.15808 | 0.4 | 0.01042 |
| 3,000 | 78.11854 | 0.3 | 0.00781 |
| 2,000 | 52.07893 | 0.2 | 0.00521 |
| 1,000 | 26.03950 | 0.1 | 0.00260 |
| 900 | 23.43555 | 0.09 | 0.00234 |
| 800 | 20.83165 | 0.08 | 0.00208 |
| 700 | 18.22764 | 0.07 | 0.00182 |
| 600 | 15.62376 | 0.06 | 0.00156 |
| 500 | 13.01975 | 0.05 | 0.00130 |
| 400 | 10.41580 | 0.04 | 0.00104 |
| 300 | 7.81190 | 0.03 | 0.00078 |
| 200 | 5.20789 | 0.02 | 0.00052 |
| 100 | 2.60401 | 0.01 | 0.00026 |
| 90 | 2.34356 | 0.009 | 0.00023 |
| 80 | 2.08315 | 0.008 | 0.00021 |
| 70 | 1.82276 | 0.007 | 0.00018 |
| 60 | 1.56236 | 0.006 | 0.00016 |
| 50 | 1.30197 | 0.005 | 0.00013 |
| 40 | 1.04159 | 0.004 | 0.00010 |
| 30 | 0.78118 | 0.003 | 0.00008 |
| 20 | 0.52079 | 0.002 | 0.00005 |
| 10 | 0.26039 | 0.001 | 0.00003 |
| 9 | 0.23435 | | |
| 8 | 0.20831 | | |
| 7 | 0.18227 | | |
| 6 | 0.15623 | | |
| 5 | 0.13019 | | |
| 4 | 0.10416 | | |
| 3 | 0.07812 | | |
| 2 | 0.05208 | | |
| 1 | 0.02604 | | |

High tare nominal pressure, psi
30

$M_a$ = 0.78118 lbs

TABLE 4. - Corrected pressure, $\frac{M_a \, g_1/g_s}{A_o}$

| Nominal pressure | Corrected pressure | Nominal pressure | Corrected pressure |
|---|---|---|---|
| 12,000 | 11,983.6985 | | |
| 11,000 | 10,985.0574 | | |
| 10,000 | 9,986.4137 | | |
| 9,000 | 8,987.7726 | 0.9 | 0.8989 |
| 8,000 | 7,989.1273 | 0.8 | 0.7988 |
| 7,000 | 6,990.4844 | 0.7 | 0.6991 |
| 6,000 | 5,991.8414 | 0.6 | 0.5990 |
| 5,000 | 4,993.1984 | 0.5 | 0.4993 |
| 4,000 | 3,994.5581 | 0.4 | 0.3996 |
| 3,000 | 2,995.9178 | 0.3 | 0.2995 |
| 2,000 | 1,997.2748 | 0.2 | 0.1998 |
| 1,000 | 998.6388 | 0.1 | 0.0997 |
| 900 | 898.7749 | 0.09 | 0.0897 |
| 800 | 798.9129 | 0.08 | 0.0798 |
| 700 | 699.0467 | 0.07 | 0.0698 |
| 600 | 599.1856 | 0.06 | 0.0598 |
| 500 | 499.3194 | 0.05 | 0.0499 |
| 400 | 399.4555 | 0.04 | 0.0399 |
| 300 | 299.5935 | 0.03 | 0.0299 |
| 200 | 199.7274 | 0.02 | 0.0199 |
| 100 | 99.8662 | 0.01 | 0.0100 |
| 90 | 89.8777 | 0.009 | 0.0088 |
| 80 | 79.8907 | 0.008 | 0.0081 |
| 70 | 69.9045 | 0.007 | 0.0069 |
| 60 | 59.9179 | 0.006 | 0.0061 |
| 50 | 49.9317 | 0.005 | 0.0050 |
| 40 | 39.9459 | 0.004 | 0.0038 |
| 30 | 29.9590 | 0.003 | 0.0031 |
| 20 | 19.9728 | 0.002 | 0.0019 |
| 10 | 9.9862 | 0.001 | 0.0012 |
| 9 | 8.9875 | | |
| 8 | 7.9889 | | |
| 7 | 6.9902 | | |
| 6 | 5.9916 | | |
| 5 | 4.9929 | | |
| 4 | 3.9946 | | |
| 3 | 2.9960 | | |
| 2 | 1.9973 | | |
| 1 | 0.9987 | | |

High tare nominal pressure=30 psi
Corrected pressure = 29.9590 psi

TABLE 5. - Density of dry air, grams/liter

| P,mm \ t,°C | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 660 | 1.0463 | 1.0428 | 1.0392 | 1.0357 | 1.0322 | 1.0287 | 1.0253 | 1.0219 | 1.0184 | 1.0151 | 1.0117 |
| 661 | 1.0479 | 1.0443 | 1.0408 | 1.0373 | 1.0338 | 1.0303 | 1.0268 | 1.0234 | 1.0200 | 1.0166 | 1.0132 |
| 662 | 1.0495 | 1.0459 | 1.0424 | 1.0388 | 1.0353 | 1.0318 | 1.0284 | 1.0249 | 1.0215 | 1.0181 | 1.0148 |
| 663 | 1.0511 | 1.0475 | 1.0439 | 1.0404 | 1.0369 | 1.0334 | 1.0299 | 1.0265 | 1.0231 | 1.0197 | 1.0163 |
| 664 | 1.0527 | 1.0491 | 1.0455 | 1.0420 | 1.0384 | 1.0350 | 1.0315 | 1.0280 | 1.0246 | 1.0212 | 1.0178 |
| 665 | 1.0542 | 1.0506 | 1.0471 | 1.0435 | 1.0400 | 1.0365 | 1.0330 | 1.0296 | 1.0262 | 1.0228 | 1.0194 |
| 666 | 1.0558 | 1.0522 | 1.0486 | 1.0451 | 1.0416 | 1.0381 | 1.0346 | 1.0311 | 1.0277 | 1.0243 | 1.0209 |
| 667 | 1.0574 | 1.0538 | 1.0502 | 1.0467 | 1.0431 | 1.0396 | 1.0361 | 1.0327 | 1.0292 | 1.0258 | 1.0224 |
| 668 | 1.0590 | 1.0554 | 1.0518 | 1.0482 | 1.0447 | 1.0412 | 1.0377 | 1.0342 | 1.0308 | 1.0274 | 1.0240 |
| 669 | 1.0606 | 1.0570 | 1.0534 | 1.0498 | 1.0463 | 1.0427 | 1.0392 | 1.0358 | 1.0323 | 1.0289 | 1.0255 |
| 670 | 1.0622 | 1.0585 | 1.0549 | 1.0514 | 1.0478 | 1.0443 | 1.0408 | 1.0373 | 1.0339 | 1.0304 | 1.0270 |
| 671 | 1.0637 | 1.0601 | 1.0565 | 1.0529 | 1.0494 | 1.0459 | 1.0424 | 1.0389 | 1.0354 | 1.0320 | 1.0286 |
| 672 | 1.0653 | 1.0617 | 1.0581 | 1.0545 | 1.0509 | 1.0474 | 1.0439 | 1.0404 | 1.0370 | 1.0335 | 1.0301 |
| 673 | 1.0669 | 1.0633 | 1.0597 | 1.0561 | 1.0525 | 1.0490 | 1.0455 | 1.0420 | 1.0385 | 1.0350 | 1.0316 |
| 674 | 1.0685 | 1.0649 | 1.0612 | 1.0576 | 1.0541 | 1.0505 | 1.0470 | 1.0435 | 1.0400 | 1.0366 | 1.0332 |
| 675 | 1.0701 | 1.0664 | 1.0628 | 1.0592 | 1.0556 | 1.0521 | 1.0486 | 1.0451 | 1.0416 | 1.0381 | 1.0347 |
| 676 | 1.0717 | 1.0680 | 1.0644 | 1.0608 | 1.0572 | 1.0536 | 1.0501 | 1.0466 | 1.0431 | 1.0397 | 1.0362 |
| 677 | 1.0732 | 1.0696 | 1.0660 | 1.0623 | 1.0588 | 1.0552 | 1.0517 | 1.0482 | 1.0447 | 1.0412 | 1.0377 |
| 678 | 1.0748 | 1.0712 | 1.0675 | 1.0639 | 1.0603 | 1.0568 | 1.0532 | 1.0497 | 1.0462 | 1.0427 | 1.0393 |
| 679 | 1.0764 | 1.0727 | 1.0691 | 1.0655 | 1.0619 | 1.0583 | 1.0548 | 1.0512 | 1.0477 | 1.0443 | 1.0408 |
| 680 | 1.0780 | 1.0743 | 1.0707 | 1.0671 | 1.0635 | 1.0599 | 1.0563 | 1.0528 | 1.0493 | 1.0458 | 1.0423 |

TABLE 5. - Density of dry air, grams/liter

| t,°C / P mm | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 660 | 1.0463 | 1.0428 | 1.0392 | 1.0357 | 1.0322 | 1.0287 | 1.0253 | 1.0219 | 1.0184 | 1.0151 | 1.0117 |
| 661 | 1.0479 | 1.0443 | 1.0408 | 1.0373 | 1.0338 | 1.0303 | 1.0268 | 1.0234 | 1.0200 | 1.0166 | 1.0132 |
| 662 | 1.0495 | 1.0459 | 1.0424 | 1.0388 | 1.0353 | 1.0318 | 1.0284 | 1.0249 | 1.0215 | 1.0181 | 1.0148 |
| 663 | 1.0511 | 1.0475 | 1.0439 | 1.0404 | 1.0369 | 1.0334 | 1.0299 | 1.0265 | 1.0231 | 1.0197 | 1.0163 |
| 664 | 1.0527 | 1.0491 | 1.0455 | 1.0420 | 1.0384 | 1.0350 | 1.0315 | 1.0280 | 1.0246 | 1.0212 | 1.0178 |
| 665 | 1.0543 | 1.0506 | 1.0471 | 1.0435 | 1.0400 | 1.0365 | 1.0330 | 1.0296 | 1.0262 | 1.0228 | 1.0194 |
| 666 | 1.0558 | 1.0522 | 1.0486 | 1.0451 | 1.0416 | 1.0381 | 1.0346 | 1.0311 | 1.0277 | 1.0243 | 1.0209 |
| 667 | 1.0574 | 1.0538 | 1.0502 | 1.0467 | 1.0431 | 1.0396 | 1.0361 | 1.0327 | 1.0292 | 1.0258 | 1.0224 |
| 668 | 1.0590 | 1.0554 | 1.0518 | 1.0482 | 1.0447 | 1.0412 | 1.0377 | 1.0342 | 1.0308 | 1.0274 | 1.0240 |
| 669 | 1.0606 | 1.0570 | 1.0534 | 1.0498 | 1.0463 | 1.0427 | 1.0392 | 1.0358 | 1.0323 | 1.0289 | 1.0255 |
| 670 | 1.0622 | 1.0585 | 1.0549 | 1.0514 | 1.0478 | 1.0443 | 1.0408 | 1.0373 | 1.0339 | 1.0304 | 1.0270 |
| 671 | 1.0637 | 1.0601 | 1.0565 | 1.0529 | 1.0494 | 1.0459 | 1.0424 | 1.0389 | 1.0354 | 1.0320 | 1.0286 |
| 672 | 1.0653 | 1.0617 | 1.0581 | 1.0545 | 1.0509 | 1.0474 | 1.0439 | 1.0404 | 1.0370 | 1.0335 | 1.0301 |
| 673 | 1.0669 | 1.0633 | 1.0597 | 1.0561 | 1.0525 | 1.0490 | 1.0455 | 1.0420 | 1.0385 | 1.0350 | 1.0316 |
| 674 | 1.0685 | 1.0649 | 1.0612 | 1.0576 | 1.0541 | 1.0505 | 1.0470 | 1.0435 | 1.0400 | 1.0366 | 1.0332 |
| 675 | 1.0701 | 1.0664 | 1.0628 | 1.0592 | 1.0556 | 1.0521 | 1.0486 | 1.0451 | 1.0416 | 1.0381 | 1.0347 |
| 676 | 1.0717 | 1.0680 | 1.0644 | 1.0608 | 1.0572 | 1.0536 | 1.0501 | 1.0466 | 1.0431 | 1.0397 | 1.0362 |
| 677 | 1.0732 | 1.0696 | 1.0660 | 1.0623 | 1.0588 | 1.0552 | 1.0517 | 1.0482 | 1.0447 | 1.0412 | 1.0377 |
| 678 | 1.0748 | 1.0712 | 1.0675 | 1.0639 | 1.0603 | 1.0568 | 1.0532 | 1.0497 | 1.0462 | 1.0427 | 1.0393 |
| 679 | 1.0764 | 1.0727 | 1.0691 | 1.0655 | 1.0619 | 1.0583 | 1.0548 | 1.0513 | 1.0477 | 1.0443 | 1.0408 |
| 680 | 1.0780 | 1.0743 | 1.0707 | 1.0671 | 1.0635 | 1.0599 | 1.0563 | 1.0528 | 1.0493 | 1.0458 | 1.0423 |

TABLE 6. - Buoyancy correction factor for dry air, $(1 - \rho_a/\rho_b)$

| P, mm \ t, °C | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|
| 600 | 0.9998755 | 0.9998759 | 0.9998763 | 0.9998768 | 0.9998772 | 0.9998776 |
| 661 | 0.9998753 | 0.9998757 | 0.9998761 | 0.9998766 | 0.9998770 | 0.9998774 |
| 662 | 0.9998751 | 0.9998755 | 0.9998760 | 0.9998764 | 0.9998768 | 0.9998772 |
| 663 | 0.9998749 | 0.9998753 | 0.9998758 | 0.9998762 | 0.9998766 | 0.9998770 |
| 664 | 0.9998747 | 0.9998752 | 0.9998756 | 0.9998760 | 0.9998764 | 0.9998768 |
| 665 | 0.9998745 | 0.9998750 | 0.9998754 | 0.9998758 | 0.9998762 | 0.9998767 |
| 666 | 0.9998744 | 0.9998748 | 0.9998752 | 0.9998756 | 0.9998761 | 0.9998765 |
| 667 | 0.9998742 | 0.9998746 | 0.9998750 | 0.9998754 | 0.9998759 | 0.9998763 |
| 668 | 0.9998740 | 0.9998744 | 0.9998748 | 0.9998753 | 0.9998757 | 0.9998761 |
| 669 | 0.9998738 | 0.9998742 | 0.9998746 | 0.9998751 | 0.9998755 | 0.9998759 |
| 670 | 0.9998736 | 0.9998740 | 0.9998745 | 0.9998749 | 0.9998753 | 0.9998757 |
| 671 | 0.9998734 | 0.9998738 | 0.9998743 | 0.9998747 | 0.9998751 | 0.9998755 |
| 672 | 0.9998732 | 0.9998737 | 0.9998741 | 0.9998745 | 0.9998749 | 0.9998754 |
| 673 | 0.9998730 | 0.9998735 | 0.9998739 | 0.9998743 | 0.9998748 | 0.9998752 |
| 674 | 0.9998728 | 0.9998733 | 0.9998737 | 0.9998741 | 0.9998746 | 0.9998750 |
| 675 | 0.9998727 | 0.9998731 | 0.9998735 | 0.9998740 | 0.9998744 | 0.9998748 |
| 676 | 0.9998725 | 0.9998929 | 0.9998733 | 0.9998738 | 0.9998742 | 0.9998746 |
| 677 | 0.9998723 | 0.9998727 | 0.9998732 | 0.9998736 | 0.9998740 | 0.9998744 |
| 678 | 0.9998721 | 0.9998725 | 0.9998730 | 0.9998734 | 0.9998738 | 0.9998742 |
| 679 | 0.9998719 | 0.9998723 | 0.9998728 | 0.9998732 | 0.9998736 | 0.9998741 |
| 680 | 0.9998717 | 0.9998722 | 0.9998726 | 0.9998730 | 0.9998734 | 0.9998739 |

TABLE 6. - Buoyancy correction factor for dry air, $(1 - \rho_a/\rho_b)$(Con)

| P, mm \ t, °C | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|
| 660 | 0.9998780 | 0.9998784 | 0.9998788 | 0.9998792 | 0.9998796 |
| 661 | 0.9998778 | 0.9998782 | 0.9998786 | 0.9998790 | 0.9998794 |
| 662 | 0.9998776 | 0.9998780 | 0.9998784 | 0.9998788 | 0.9998792 |
| 663 | 0.9998774 | 0.9998778 | 0.9998783 | 0.9998787 | 0.9998791 |
| 664 | 0.9998773 | 0.9998777 | 0.9998781 | 0.9998785 | 0.9998789 |
| 665 | 0.9998771 | 0.9998775 | 0.9998779 | 0.9998783 | 0.9998787 |
| 666 | 0.9998769 | 0.9998773 | 0.9998777 | 0.9998781 | 0.9998785 |
| 667 | 0.9998767 | 0.9998771 | 0.9998775 | 0.9998779 | 0.9998783 |
| 668 | 0.9998765 | 0.9998769 | 0.9998773 | 0.9998777 | 0.9998781 |
| 669 | 0.9998763 | 0.9998767 | 0.9998772 | 0.9998776 | 0.9998780 |
| 670 | 0.9998761 | 0.9998766 | 0.9998770 | 0.9998774 | 0.9998778 |
| 671 | 0.9998760 | 0.9998764 | 0.9998768 | 0.9998772 | 0.9998776 |
| 672 | 0.9998758 | 0.9998762 | 0.9998766 | 0.9998770 | 0.9998774 |
| 673 | 0.9998756 | 0.9998760 | 0.9998764 | 0.9998768 | 0.9998772 |
| 674 | 0.9998754 | 0.9998758 | 0.9998762 | 0.9998766 | 0.9998771 |
| 675 | 0.9998752 | 0.9998756 | 0.9998761 | 0.9998765 | 0.9998769 |
| 676 | 0.9998750 | 0.9998755 | 0.9998759 | 0.9998763 | 0.9998767 |
| 677 | 0.9998749 | 0.9998753 | 0.9998757 | 0.9998761 | 0.9998765 |
| 678 | 0.9998747 | 0.9998751 | 0.9998755 | 0.9998759 | 0.9998763 |
| 679 | 0.9998745 | 0.9998749 | 0.9998753 | 0.9998757 | 0.9998761 |
| 680 | 0.9998743 | 0.9998747 | 0.9998751 | 0.9998755 | 0.9998760 |

TABLE 7.-Pressure distortion correction factor for piston gage No. 9274, $\frac{1}{1 + bP}$

| P, psi | $\frac{1}{1 + bP}$ | P, psi | $\frac{1}{1 + bP}$ | P, psi | $\frac{1}{1 + bP}$ |
|---|---|---|---|---|---|
| 12,100 | 1.0004235 | | | | |
| 12,000 | 1.0004200 | | | | |
| 11,900 | 1.0004165 | 8,900 | 1.0003115 | 5,900 | 1.0002065 |
| 11,800 | 1.0004130 | 8,800 | 1.0003080 | 5,800 | 1.0002030 |
| 11,700 | 1.0004095 | 8,700 | 1.0003045 | 5,700 | 1.0001995 |
| 11,600 | 1.0004060 | 8,600 | 1.0003010 | 5,600 | 1.0001960 |
| 11,500 | 1.0004025 | 8,500 | 1.0002975 | 5,500 | 1.0001925 |
| 11,400 | 1.0003990 | 8,400 | 1.0002940 | 5,400 | 1.0001890 |
| 11,300 | 1.0003955 | 8,300 | 1.0002905 | 5,300 | 1.0001855 |
| 11,200 | 1.0003920 | 8,200 | 1.0002870 | 5,200 | 1.0001820 |
| 11,100 | 1.0003885 | 8,100 | 1.0002835 | 5,100 | 1.0001785 |
| 11,000 | 1.0003850 | 8,000 | 1.0002800 | 5,000 | 1.0001750 |
| 10,900 | 1.0003815 | 7,900 | 1.0002765 | 4,900 | 1.0001715 |
| 10,800 | 1.0003780 | 7,800 | 1.0002730 | 4,800 | 1.0001680 |
| 10,700 | 1.0003745 | 7,700 | 1.0002695 | 4,700 | 1.0001645 |
| 10,600 | 1.0003710 | 7,600 | 1.0002660 | 4,600 | 1.0001610 |
| 10,500 | 1.0003675 | 7,500 | 1.0002625 | 4,500 | 1.0001575 |
| 10,400 | 1.0003640 | 7,400 | 1.0002590 | 4,400 | 1.0001540 |
| 10,300 | 1.0003605 | 7,300 | 1.0002555 | 4,300 | 1.0001505 |
| 10,200 | 1.0003570 | 7,200 | 1.0002520 | 4,200 | 1.0001470 |
| 10,100 | 1.0003535 | 7,100 | 1.0002485 | 4,100 | 1.0001435 |
| 10,000 | 1.0003500 | 7,000 | 1.0002450 | 4,000 | 1.0001400 |
| 9,900 | 1.0003465 | 6,900 | 1.0002415 | 3,900 | 1.0001365 |
| 9,800 | 1.0003430 | 6,800 | 1.0002380 | 3,800 | 1.0001330 |
| 9,700 | 1.0003395 | 6,700 | 1.0002345 | 3,700 | 1.0001295 |
| 9,600 | 1.0003360 | 6,600 | 1.0002310 | 3,600 | 1.0001260 |
| 9,500 | 1.0003325 | 6,500 | 1.0002275 | 3,500 | 1.0001225 |
| 9,400 | 1.0003290 | 6,400 | 1.0002240 | 3,400 | 1.0001190 |
| 9,300 | 1.0003255 | 6,300 | 1.0002205 | 3,300 | 1.0001155 |
| 9,200 | 1.0003220 | 6,200 | 1.0002170 | 3,200 | 1.0001120 |
| 9,100 | 1.0003185 | 6,100 | 1.0002135 | 3,100 | 1.0001085 |
| 9,000 | 1.0003150 | 6,000 | 1.0002100 | 3,000 | 1.0001050 |

TABLE 7.-Pressure distortion correction factor for piston gage No. 9274, $\frac{1}{1 + bP}$

| P, psi | $\frac{1}{1 + bP}$ |
|---|---|
| 2,900 | 1.0001015 |
| 2,800 | 1.0000980 |
| 2,700 | 1.0000945 |
| 2,600 | 1.0000910 |
| 2,500 | 1.0000875 |
| 2,400 | 1.0000840 |
| 2,300 | 1.0000805 |
| 2,200 | 1.0000770 |
| 2,100 | 1.0000735 |
| 2,000 | 1.0000700 |
| 1,900 | 1.0000665 |
| 1,800 | 1.0000630 |
| 1,700 | 1.0000595 |
| 1,600 | 1.0000560 |
| 1,500 | 1.0000525 |
| 1,400 | 1.0000490 |
| 1,300 | 1.0000455 |
| 1,200 | 1.0000420 |
| 1,100 | 1.0000385 |
| 1,000 | 1.0000350 |
| 900 | 1.0000315 |
| 800 | 1.0000280 |
| 700 | 1.0000245 |
| 600 | 1.0000210 |
| 500 | 1.0000175 |
| 400 | 1.0000140 |
| 300 | 1.0000105 |
| 200 | 1.0000070 |
| 100 | 1.0000035 |
| 90 | 1.0000032 |
| 80 | 1.0000028 |
| 70 | 1.0000025 |
| 60 | 1.0000021 |
| 50 | 1.0000018 |
| 40 | 1.0000014 |
| 30 | 1.0000011 |
| 20 | 1.0000007 |
| 10 | 1.0000004 |

TABLE 8. - Temperature correction factor for piston gage No. 9274, $\frac{1}{1 + c(t - 25)}$

| t, °C | $\frac{1}{1 + c\,(t - 25)}$ | t, °C | $\frac{1}{1 + c\,(t - 25)}$ |
|---|---|---|---|
| 20.0 | 1.0000850 | 24.0 | 1.0000170 |
| 20.1 | 1.0000833 | 24.1 | 1.0000153 |
| 20.2 | 1.0000816 | 24.2 | 1.0000136 |
| 20.3 | 1.0000799 | 24.3 | 1.0000119 |
| 20.4 | 1.0000782 | 24.4 | 1.0000102 |
| 20.5 | 1.0000765 | 24.5 | 1.0000085 |
| 20.6 | 1.0000748 | 24.6 | 1.0000068 |
| 20.7 | 1.0000731 | 24.7 | 1.0000051 |
| 20.8 | 1.0000714 | 24.8 | 1.0000034 |
| 20.9 | 1.0000697 | 24.9 | 1.0000017 |
| 21.0 | 1.0000680 | 25.0 | 1.0000000 |
| 21.1 | 1.0000663 | 25.1 | 0.9999983 |
| 21.2 | 1.0000646 | 25.2 | 0.9999966 |
| 21.3 | 1.0000629 | 25.3 | 0.9999949 |
| 21.4 | 1.0000612 | 25.4 | 0.9999932 |
| 21.5 | 1.0000595 | 25.5 | 0.9999915 |
| 21.6 | 1.0000578 | 25.6 | 0.9999898 |
| 21.7 | 1.0000561 | 25.7 | 0.9999881 |
| 21.8 | 1.0000544 | 25.8 | 0.9999864 |
| 21.9 | 1.0000527 | 25.9 | 0.9999847 |
| 22.0 | 1.0000510 | 26.0 | 0.9999830 |
| 22.1 | 1.0000493 | 26.1 | 0.9999813 |
| 22.2 | 1.0000476 | 26.2 | 0.9999796 |
| 22.3 | 1.0000459 | 26.3 | 0.9999779 |
| 22.4 | 1.0000442 | 26.4 | 0.9999762 |
| 22.5 | 1.0000425 | 26.5 | 0.9999745 |
| 22.6 | 1.0000408 | 26.6 | 0.9999728 |
| 22.7 | 1.0000391 | 26.7 | 0.9999711 |
| 22.8 | 1.0000374 | 26.8 | 0.9999694 |
| 22.9 | 1.0000357 | 26.9 | 0.9999677 |
| 23.0 | 1.0000340 | 27.0 | 0.9999660 |
| 23.1 | 1.0000323 | 27.1 | 0.9999643 |
| 23.2 | 1.0000306 | 27.2 | 0.9999626 |
| 23.3 | 1.0000289 | 27.3 | 0.9999609 |
| 23.4 | 1.0000272 | 27.4 | 0.9999592 |
| 23.5 | 1.0000255 | 27.5 | 0.9999575 |
| 23.6 | 1.0000238 | 27.6 | 0.9999558 |
| 23.7 | 1.0000221 | 27.7 | 0.9999541 |
| 23.8 | 1.0000204 | 27.8 | 0.9999524 |
| 23.9 | 1.0000187 | 27.9 | 0.9999507 |

TABLE 8. - Temperature correction factor for piston gage No. 9274, $\frac{1}{1 + c\ (t - 25)}$ (Con)

| t, °C | $\frac{1}{1 + c\ (t - 25)}$ |
|---|---|
| 28.0 | 0.9999490 |
| 28.1 | 0.9999473 |
| 28.2 | 0.9999456 |
| 28.3 | 0.9999439 |
| 28.4 | 0.9999422 |
| 28.5 | 0.9999405 |
| 28.6 | 0.9999388 |
| 28.7 | 0.9999371 |
| 28.8 | 0.9999354 |
| 28.9 | 0.9999337 |
| 29.0 | 0.9999320 |
| 29.1 | 0.9999303 |
| 29.2 | 0.9999286 |
| 29.3 | 0.9999269 |
| 29.4 | 0.9999252 |
| 29.5 | 0.9999235 |
| 29.6 | 0.9999218 |
| 29.7 | 0.9999201 |
| 29.8 | 0.9999184 |
| 29.9 | 0.9999167 |
| 30.0 | 0.9999150 |

TABLE 9. - Correction to be added to gage pressure to correct for zero shift of differential pressure cell No. 9032

| P, psi | ΔP, psi | P, psi | ΔP, psi | P, psi | ΔP, psi |
|---|---|---|---|---|---|
| 12,100 | 0.0224 | | | | |
| 12,000 | 0.0222 | | | | |
| 11,900 | 0.0220 | 7,900 | 0.0146 | 3,900 | 0.0072 |
| 11,800 | 0.0218 | 7,800 | 0.0144 | 3,800 | 0.0070 |
| 11,700 | 0.0216 | 7,700 | 0.0142 | 3,700 | 0.0068 |
| 11,600 | 0.0215 | 7,600 | 0.0141 | 4,600 | 0.0067 |
| 11,500 | 0.0213 | 7,500 | 0.0139 | 3,500 | 0.0065 |
| 11,400 | 0.0211 | 7,400 | 0.0137 | 3,400 | 0.0063 |
| 11,300 | 0.0209 | 7,300 | 0.0135 | 3,300 | 0.0061 |
| 11,200 | 0.0207 | 7,200 | 0.0133 | 3,200 | 0.0059 |
| 11,100 | 0.0205 | 7,100 | 0.0131 | 3,100 | 0.0057 |
| 11,000 | 0.0204 | 7,000 | 0.0130 | 3,000 | 0.0056 |
| 10,900 | 0.0202 | 6,900 | 0.0128 | 2,900 | 0.0054 |
| 10,800 | 0.0200 | 6,800 | 0.0126 | 2,800 | 0.0052 |
| 10,700 | 0.0198 | 6,700 | 0.0124 | 2,700 | 0.0050 |
| 10,600 | 0.0196 | 6,600 | 0.0122 | 2,600 | 0.0048 |
| 10,500 | 0.0194 | 6,500 | 0.0120 | 2,500 | 0.0046 |
| 10,400 | 0.0192 | 6,400 | 0.0118 | 2,400 | 0.0044 |
| 10,300 | 0.0191 | 6,300 | 0.0117 | 2,300 | 0.0043 |
| 10,200 | 0.0189 | 6,200 | 0.0115 | 2,200 | 0.0041 |
| 10,100 | 0.0187 | 6,100 | 0.0113 | 2,100 | 0.0039 |
| 10,000 | 0.0185 | 6,000 | 0.0111 | 2,000 | 0.0037 |
| 9,900 | 0.0183 | 5,900 | 0.0109 | 1,900 | 0.0035 |
| 9,800 | 0.0181 | 5,800 | 0.0107 | 1,800 | 0.0033 |
| 9,700 | 0.0179 | 5,700 | 0.0105 | 1,700 | 0.0031 |
| 9,600 | 0.0178 | 5,600 | 0.0104 | 1,600 | 0.0030 |
| 9,500 | 0.0176 | 5,500 | 0.0102 | 1,500 | 0.0028 |
| 9,400 | 0.0174 | 5,400 | 0.0100 | 1,400 | 0.0026 |
| 9,300 | 0.0172 | 5,300 | 0.0098 | 1,300 | 0.0024 |
| 9,200 | 0.0170 | 5,200 | 0.0096 | 1,200 | 0.0022 |
| 9,100 | 0.0168 | 5,100 | 0.0094 | 1,100 | 0.0020 |
| 9,000 | 0.0167 | 5,000 | 0.0093 | 1,000 | 0.0019 |
| 8,900 | 0.0165 | 4,900 | 0.0091 | 900 | 0.0017 |
| 8,800 | 0.0163 | 4,800 | 0.0089 | 800 | 0.0015 |
| 8,700 | 0.0161 | 4,700 | 0.0087 | 700 | 0.0013 |
| 8,600 | 0.0159 | 4,600 | 0.0085 | 600 | 0.0011 |
| 8,500 | 0.0157 | 4,500 | 0.0083 | 500 | 0.0009 |
| 8,400 | 0.0155 | 4,400 | 0.0081 | 400 | 0.0007 |
| 8,300 | 0.0154 | 4,300 | 0.0080 | 300 | 0.0006 |
| 8,200 | 0.0152 | 4,200 | 0.0078 | 200 | 0.0004 |
| 8,100 | 0.0150 | 4,100 | 0.0076 | 100 | 0.0002 |
| 8,000 | 0.0148 | 4,000 | 0.0074 | | |