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# ISOBARIC HEAT CAPACITY OF NITRIC OXIDE
# OVER A WIDE RANGE OF TEMPERATURE AND PRESSURE

By

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## SUMMARY

The effect of pressure and temperature on the isobaric heat capacity and the heat capacity at constant volume for nitric oxide relative to the ideal gas state is presented. Results are reported for pressures ranging from 0 to 6000 PSIA and for temperatures ranging from 300 to 1800°R.

Based on the Benedict-Webb-Rubin equation of state, an equation was derived for the deviation of isobaric heat capacity from the ideal gas state. Graphs and tables relating the isobaric heat capacity and the deviation of heat capacity at constant volume to pressure and temperature for nitric oxide are included.

The results show that the effect of pressure on the isobaric heat capacity must be considered in thermal calculations, since a considerable error is introduced if the pressure effect is neglected. If the effect of pressure is neglected, the greatest error would occur near the critical point.

Also included is a comparison of the calculated data with those of Opfell, Schlinger and Sage.

# INTRODUCTION

The lack of basic knowledge at elevated temperatures and pressures has become more apparent in recent years with the development of new processes and with the advancement of engineering. As a result, the petroleum industry is making a continued effort to accumulate more accurate thermodynamic data over an increasing range of temperatures and pressures. The American Petroleum Institute Research Project 44 (1) lists accurate thermodynamic properties over the temperature and pressure range normally encountered, and at elevated temperatures. However, the effect of pressure on the heat capacity of gases and vapors is, in general, neglected. The absence of these data is due primarily to the difficulty encountered in making calorimetric measurements at high pressure.

There are two methods available which may be used to gather the desired information. The first method involves the use of a generalized correlation, of which the correlations presented by: Edminster (2), Watson and Smith (3), and Hougen and Watson (4) are excellent examples. The second method requires the use of an equation of state which is exemplified by the equations of van der Waals, Berthelot (5), Dieterici (5), Onnes (5), Wohl (6), Keyes (7), Beattie and Bridgeman (8), and Benedict, Webb and Rubin (9).

If generalized correlations are used to determine the effect of pressure and temperature on heat capacity, a full knowledge of the limitations of the correlation must be had. On the other hand, in order to apply one of the equations of state for this purpose, it is necessary to obtain the empirical constants for the specific fluid being considered.

Of the eight equations of state mentioned above, and the several hundred other equations available (most of the equations are applicable to one fluid over a limited range of temperatures and pressures), the Beattie-Bridgeman and the Benedict, Webb and Rubin equations are the two most useful for the interpolation and extrapolation of experimental data when a high degree of precision is desired.

The Beattie-Bridgeman equation is one of the most widely used equations of state. It employs five empirical constants and has been found to agree within a fraction of one per cent with experimental data for a number of gases over a wide range of conditions. An extensive tabulation of the constants for the Beattie-Bridgeman equation and a list of the range of conditions for which they apply, is given in Dodge (10). The equation was not designed to reproduce properties of gases in the critical range or below the critical volume. Ellenwood, Kulik, and Gay (11) used the Beattie-Bridgeman equation of state as a basis in computing the specific heats of air, CO, $CO_2$, $H_2$, $N_2$, $O_2$, $CH_4$ and $C_2H_4$ for the temperature range of $460^{\circ}R$ to $4500^{\circ}R$ and a pressure range of 0 to 10,000 PSIA.

Developed specifically for the lighter hydrocarbons (from the experimental data for methane, ethane, propane and n-butane) the Benedict-Webb-Rubin equation contains eight empirical constants. The equation is similar to the van der Waals equation, in that it assumes the continuity of the liquid and gaseous states. The same equation may be used to reproduce P-V-T data accurately for both the liquid and gaseous states of a fluid, up to approximately 1.8 times the critical density. According to Hougen and Watson the Benedict-Webb-Rubin equation holds within 0.34 per cent, even at gas densities which are double the critical density for methane, ethane, propane and n-butane.

Employing the Benedict-Webb-Rubin equation of state isobaric heat capacities relative to the ideal gas state have been computed over a wide range of pressures and temperatures: for methane by Sledjeski (12, 13), for propane by Seifarth (14, 15), for n-butane by Glueck (16), and for ethylene by Sibilia (17). Glueck and Sibilia also report the variation of the heat capacity at constant volume relative to the ideal gas state over a wide temperature and pressure range for n-butane and ethylene respectively.

In the present work the isobaric heat capacity at constant pressure of nitric oxide, relative to the ideal gas state from 0 to 6000 PSIA and from 300 to 1800°R is computed using the Benedict-Webb-Rubin equation. Also presented, is the variation of the heat capacity at constant volume relative to the ideal gas state for nitric oxide over the same pressure and temperature range.

The Benedict-Webb-Rubin constants were evaluated by Opfell, Schlinger and Sage (18) who report a standard deviation of 0.00458 in the compressibility factor form - 100°F to 220°F and for pressures up to 3000 PSIA. Opfell, Schlinger and Sage report that these constants do not adequately describe the properties of nitric oxide in the critical or heterogeneous regions. They state that at temperatures of 100°R and 200°R marked disagreement occured between the estimated behavior and the behavior predicted by the Benedict-Webb-Rubin equation using these constants. Therefore, no attempt was made to predict the properties of nitric oxide below 300°R. However, this work does include calculations which represent an extrapolation of the available data used by Opfell, Schlinger and Sage from 680° to 1800°R and from 3000 to 6000 PSIA.

## DERIVATION OF THE EQUATION FOR ($Cp-Cp^*$) FROM THE BENEDICT-WEBB-RUBIN EQUATION OF STATE

The Benedict-Webb-Rubin Equation of State (9) is:

(E-1) $$p = RTd + (B_oRT - A_o - C_oT^{-2})d^2 + (bRT - a)d^3 + a\alpha d^6 + cd^3(1+\gamma d^2)T^{-2}e^{-\gamma d^2}$$

Substituting molal volume for density in equation (E-1):

(E-2) $$p = RTV^{-1} + (B_oRT - A_o - C_oT^{-2})V^{-2} + (bRT - a)V^{-3}$$
$$a\alpha V^{-6} + cV^{-3}(1+\gamma V^{-2})T^{-2}e^{-\gamma V^{-2}}$$

Expanding equation (E-2):

(E-3) $$p = RTV^{-1} + B_oRTV^{-2} - A_oV^{-2} - C_oT^{-2}V^{-2} + bRTV^{-3}$$
$$-aV^{-3} + a\alpha V^{-6} + cV^{-3}T^{-2}e^{-\gamma V^{-2}} + c\gamma V^{-5}T^{-2}e^{-\gamma V^{-2}}$$

For an ideal gas:

(E-4) $$Cp^* - Cv^* = R$$

Rearranging (E-4):

(E-5) $$-Cv^* - R = -Cp^*$$

Adding Cp, the actual heat cpacity, at constant pressure to each side of equation (E-4):

(E-6) $$Cp - Cv^* - R = Cp - Cp^*$$

Adding and subtracting Cv to the left side of (E-6):

(E-7) $$(Cp - Cv) + (Cv - Cv^*) - R = Cp - Cp^*$$

Equation 90 on page 461 of Hougen and Watson (4) is as follows:

(E-8) $$(Cp - Cv) = -T\left(\frac{\delta V}{\delta T}\right)_p^2\left(\frac{\delta p}{\delta V}\right)_T$$

Equation 89 on the same page of Hougen and Watson (4) is :

(E-9) $$\left(\frac{\delta V}{\delta T}\right)_p = \frac{\left(\frac{\delta p}{\delta T}\right)_V}{\left(\frac{\delta p}{\delta V}\right)_T}$$

Substituting (E-9) into (E-8):

(E-10) $$Cp - Cv = \frac{-T\left(\frac{\delta p}{\delta T}\right)_V^2}{\left(\frac{\delta p}{\delta V}\right)_T}$$

Differentiating equation (E-3) with respect to temperature at constant volume:

(E-11) $$\left(\frac{\delta p}{\delta T}\right)_V = RV^{-1} + B_oRV^{-2} + 2C_oV^{-2}T^{-3} + bRV^{-3} - 2cV^{-3}e^{-\gamma V^{-2}}T^{-3} - 2c\gamma V^{-5}e^{-\gamma V^{-2}}T^{-3}$$

$$\text{or } \left(\frac{\delta p}{\delta T}\right)_V = RV^{-1} + (B_oR + 2C_oT^{-3})V^{-2} + bRV^{-3} - 2cV^{-3}T^{-3}e^{-\gamma V^{-2}}(1 + \gamma V^{-2})$$

Differentiating equation (E-3) with respect to volume at constant temperature:

(E-12) $$\left(\frac{\delta p}{\delta V}\right)_T = -RTV^{-2} - 2B_oRTV^{-3} + 2A_oV^{-3} + 2C_oT^{-2}V^{-3} - 3bRTV^{-4} + 3aV^{-4} - 6a\alpha V^{-7} + 2\gamma cV^{-6}T^{-2}e^{-\gamma V^{-2}} - 3cV^{-4}T^{-2}e^{-\gamma V^{-2}} + 2c\gamma^2V^{-8}T^{-2}e^{-\gamma V^{-2}} - 5c\gamma V^{-6}T^{-2}e^{-\gamma V^{-2}}$$

$$\text{or } \left(\frac{\delta p}{\delta V}\right)_T = -RTV^{-2} - 2V^{-3}(B_oRT - A_o - C_oT^{-2}) - 3V^{-4}(bRT - a) - 6a\alpha V^{-7} + cT^{-2}e^{-\gamma V^{-2}}(-3V^{-4} - 3\gamma V^{-6} + 2\gamma^2V^{-8})$$

Substituting (E-11) and (E-12) into equation (E-10):

(E-13)

$$Cp - Cv = -T\frac{\left[RV^{-1} + (B_oR + 2C_oT^{-3})V^{-2} + bRV^{-3} - 2cV^{-3}T^{-3}(1+\gamma V^{-2})e^{-\gamma V^{-2}}\right]^2}{\left[\begin{array}{l} -RTV^{-2} - 2V^{-3}(B_oRT - A_o - C_oT^{-2}) - 3V^{-4}(bRT - a) \\ -6a\alpha V^{-7} + cT^{-2}e^{-\gamma V^{-2}}(-3V^{-4} - 3\gamma V^{-6} + 2\gamma^2V^{-8}) \end{array}\right]}$$

From Hougen and Watson (4) (equation 94, page 473):

(E-14) $$\left(\frac{\delta Cv}{\delta V}\right)_T = T\left(\frac{\delta^2 p}{\delta T^2}\right)_V$$

Rearranging (E-14):

(E-15) $$dCv = T\left(\frac{\delta^2 p}{\delta T^2}\right)_v dV$$

Integrating (E-15):

(E-16) $$Cv - Cv^* = \int_{\infty}^{V} T\left(\frac{\delta^2 p}{\delta T^2}\right)_v dV$$

Differentiating equation (E-11) with respect to temperature at constant volume:

(E-17) $$\left(\frac{\delta p}{\delta T}\right)_V = -6C_oV^{-2}T^{-4} + 6cV^{-3}e^{-\gamma V^{-2}}T^{-4} + 6c\gamma V^{-5}e^{-\gamma V^{-2}}T^{-4}$$

$$\text{or } \left(\frac{\delta p}{\delta T}\right)_v = 6T^{-4}(cV^{-3}e^{-\gamma V^{-2}} + c\gamma V^{-5}e^{-\gamma V^{-2}} - C_oV^{-2})$$

Substituting (E-17) into (E-16):

(E-18) $$Cv - Cv^* = 6\,T^{-3}\int_{\infty}^{V}(cV^{-3}e^{-\gamma V^{-2}} + c\gamma V^{-5}e^{-\gamma V^{-2}} - C_oV^{-2})\,dV$$

$$\text{or } Cv - Cv^* = 6cT^{-3}\int_{\infty}^{V}(V^{-3}e^{-\gamma V^{-2}})\,dV + 6c\gamma T^{-3}\int_{\infty}^{V}(V^{-5}e^{-\gamma V^{-2}})\,dV - 6C_oT^{-3}\int_{\infty}^{V}V^{-2}dV$$

Evaluation of (E-18) yields:

(E-19) $$Cv - Cv^* = 6CT^{-3}\left[\frac{e^{-\gamma V^{-2}}}{2V^2} + \frac{e^{-\gamma V^{-2}}}{\gamma} + \frac{C_o}{cV}\right]_{\infty}^{V}$$

Substituting limits:

(E-20) $$Cv - Cv^* = 6cT^{-3}\left[\frac{e^{-\gamma V^{-2}}}{2V^2} + \frac{e^{-\gamma V^{-2}}}{\gamma} + \frac{C_o}{cV}\right] - \frac{6cT^{-3}}{\gamma}$$

Substituting equations (E-13) and (E-20) into equation (E-7) results in the desired expression for $(Cp-Cp^{*})$ in terms of the Benedict-Webb-Rubin equation of state:

$$(\text{E-21}) \quad (Cp-Cp^{*}) = -T\,\frac{\left[RV^{-1} + (B_oR + 2C_oT^{-3})V^{-2} + bRV^{-3} - 2cV^{-3}(1+\gamma V^{-2})e^{-\gamma V^{-2}}T^{-3}\right]^{2}}{\left[\begin{array}{l} -RTV^{-2} - 2V^{-3}(B_oRT - A_o - C_oT^{-2}) - 3V^{-4}(bRT-a) \\ -6a\alpha V^{-7} + cT^{-2}(-3V^{-4} - 3\gamma V^{-6} + 2\gamma^{2}V^{-8})e^{-\gamma V^{-2}} \end{array}\right]}$$

$$+ \quad 6cT^{-3}\left[\frac{e^{-\gamma V^{-2}}}{2V^{2}} + \frac{e^{-\gamma V^{-2}}}{\gamma} + \frac{C_o}{cV}\right] - \frac{6cT^{-3}}{\gamma} - R$$

## METHOD OF CALCULATION

Since the values of $Cp^*$ and $Cv^*$ are subject to constant revision as methods and techniques are improved, all calculations and graphs present the deviation of Cp and Cv from the ideal gas state. That is, all calculations and graphs are presented in the form $(Cp-Cp^*)$ and $(Cv-Cv^*)$. Table II lists the values of $Cp^*$ for nitric oxide from $-450.69^{\circ}F$ to $2200^{\circ}F$ given by API Project 44(1). $Cp^*$ values presented by Witmer (19) are listed in Table III for temperatures which range from $1^{\circ}K$ to $500^{\circ}K$.

Equation (E-2) is explicit in pressure and implicit in molal volume and temperature. Therefore, the solution of equation (E-2) is accomplished, most conveniently, by substituting assumed values of temperature and molal volume into (E-2), and solving for the pressure. Substituting the same assumed values into equation (E-21) yields the desired value of $(Cp-Cp^*)$ at the assumed temperature and the calculated pressure. Stepwise, the calculations were carried out as follows:

1. Assuming a temperature such as $300^{\circ}R$, molal volumes ranging from 1 to 20 $ft^3$/lb. mole were substituted into equation (E-2), and the equation was solved for the corresponding pressure.
2. Equation (E-11) was then used to calculate the corresponding value of $(\delta P/\delta T)_V$ for the assumed molal volumes at $300^{\circ}R$.
3. $(\delta P/\delta T)^2_V$ was obtained by squaring each of the values obtained in step 2.
4. Values of $(\delta P/\delta V)_T$ were then calculated using equation (E-12).
5. Substituting the values of $(\delta P/\delta T)^2_V$ and $(\delta P/\delta V)_T$ obtained in step 3 and 4 into equation (E-13) resulted in the evaluation of $(Cp-Cv)$.

6. Using equation (E-20) values of $(Cv-Cv^*)$ were computed for the $300^\circ R$ isotherm.

7. The substitution of the values obtained from equations (E-13) and (E-20) into equation (E-21) provided the desired values of $(Cp-Cp^*)$.

8. The procedure outlined in steps 1 through 7 was repeated for the following temperatures: $400^\circ R$, $500^\circ R$, $600^\circ R$, $700^\circ R$, $1000^\circ R$, $1800^\circ R$, and $2500^\circ R$.

A complete stepwise calculation is given in the Sample Calculation.

The data obtained by these calculations was tabulated in Table I and plotted in Figure 1. A cross-plot was made of Figure 1 which shows the deviation of heat capacity as a function of temperature for the following isobars: 100 PSIA, 200 PSIA, 500 PSIA, 1000PSIA, 2000 PSIA, 3000 PSIA, 4000 PSIA, 5000 PSIA, and 6000 PSIA. This is shown in Figure 2.

In a similar manner values of $(Cv-Cv^*)$ versus pressure were plotted in Figure 3 and cross plotted in figure 4 to show the variation of $(Cv-Cv^*)$ as a function of temperature for nine isobars.

## DISCUSSION OF RESULTS

The accuracy of the present work can not be determined, since experimental data are not available in the literature for the range covered by this work. The values presented herein, represent an extrapolation of the data of Opfell, Schlinger, and Sage (18) who report the isobaric heat capacity of nitric oxide at pressures up to 2000 PSIA in the temperature range from -100 to 220°F. The data of Opfell, Schlinger, and Sage (18) are compared to the present work in Figures 5 and 6. In order to obtain the data in the proper form $C_p$* values, given by API project 44 (1), were subtracted from the $C_p$ values reported by Opfell, Schlinger, and Sage and these data were plotted in Figure 5. In Figure 6 $C_p^*$ values presented by Witmer (19) were used in place of the values given by API project 44.

Figures 5 and 6 show close agreement between the data thus obtained and the data presented by Salzarulo. This was expected, since the present work is based on the Benedict, Webb, and Rubin constants evaluated by Opfell, Schlinger, and Sage.

The above named authors state that the Benedict- Webb-Rubin constants were established by the methods of Brough and Selleck and therefore do not necessarily give a satisfactory description of the volumetric behavior of nitric oxide beyond the ranges of temperature and pressure for which the coefficients were established (from -100 to

$220^{o}F$ and for pressures up to 3000 PSI). However, for most engineering applications, the extrapolated values for the isobaric heat capacity and the heat capacity at constant volume presented herein are sufficiently accurate. If a greater degree of accuracy is warrented, the required data must be obtained experimentally.

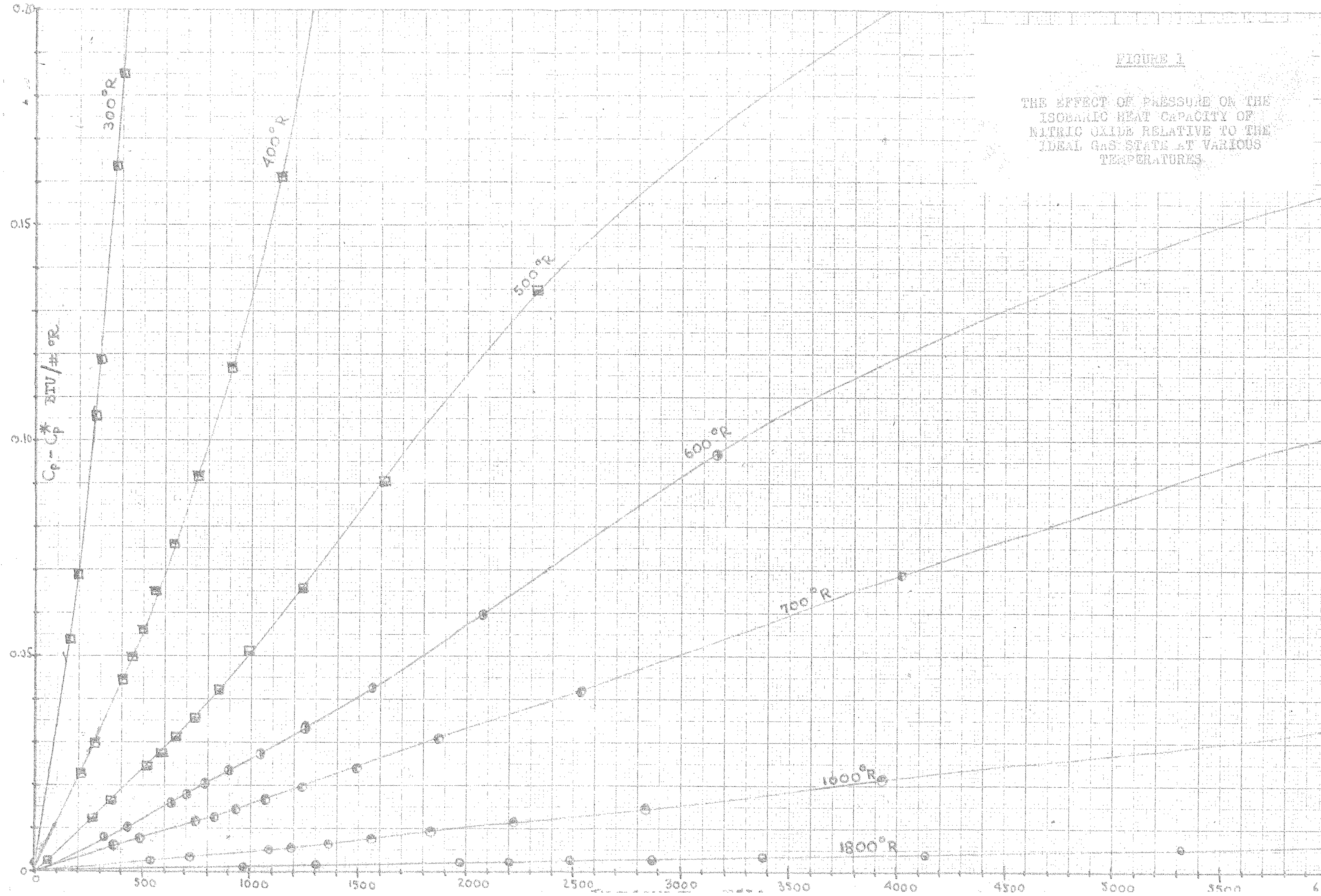



FIGURE 1

THE EFFECT OF PRESSURE ON THE ISOBARIC HEAT CAPACITY OF NITRIC OXIDE RELATIVE TO THE IDEAL GAS STATE AT VARIOUS TEMPERATURES

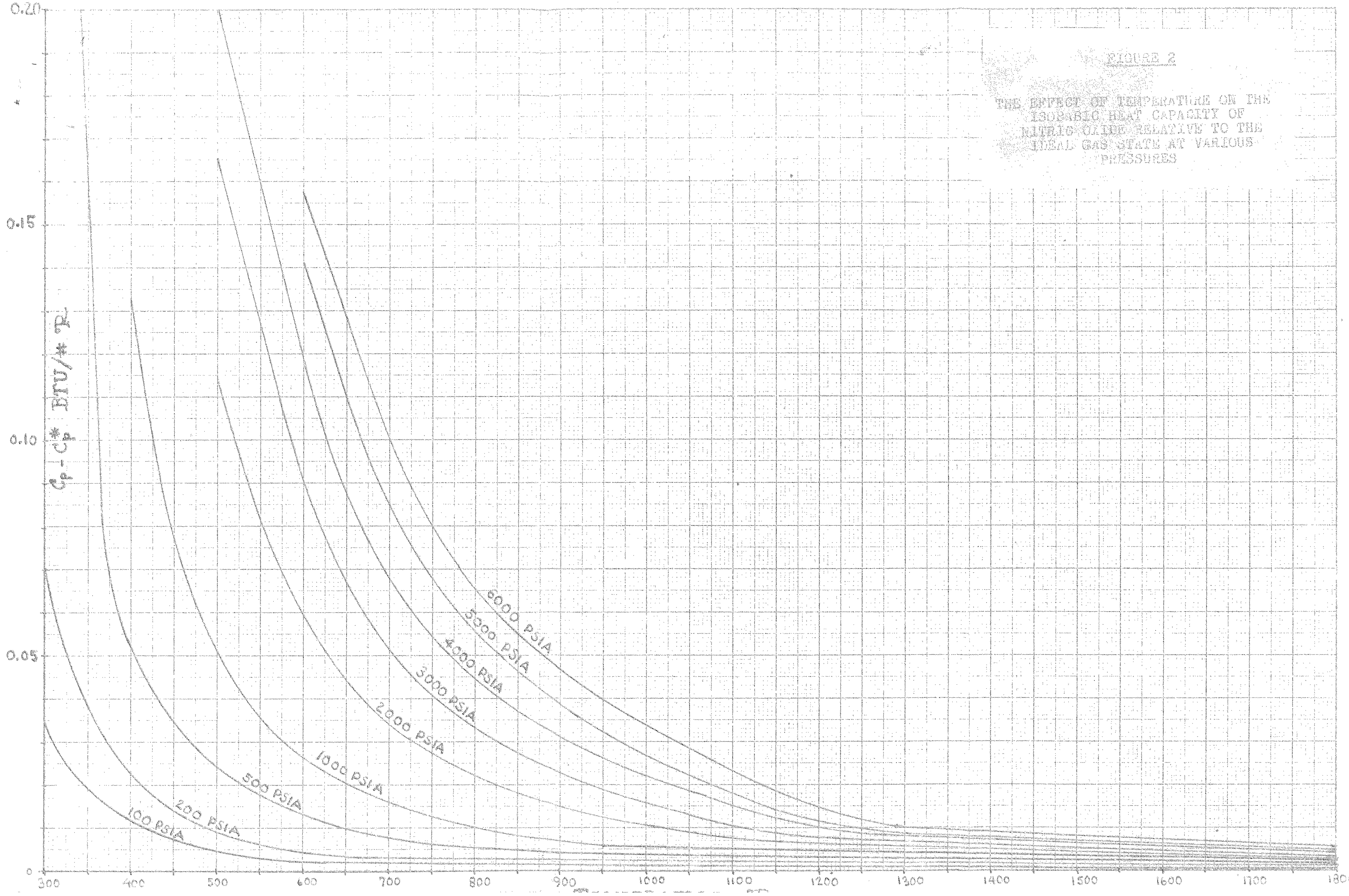



FIGURE 2

THE EFFECT OF TEMPERATURE ON THE ISOBARIC HEAT CAPACITY OF NITRIC OXIDE RELATIVE TO THE IDEAL GAS STATE AT VARIOUS PRESSURES

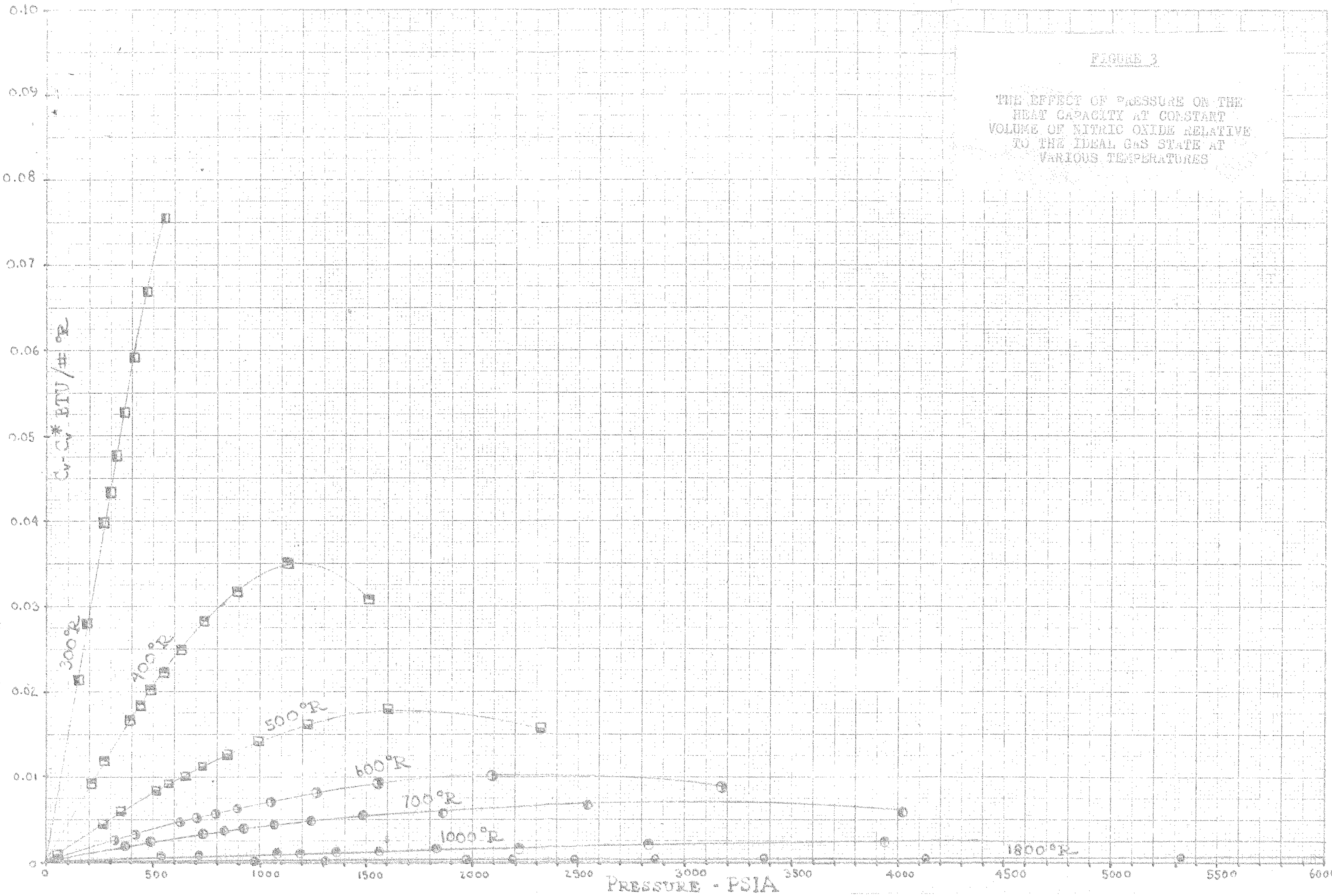
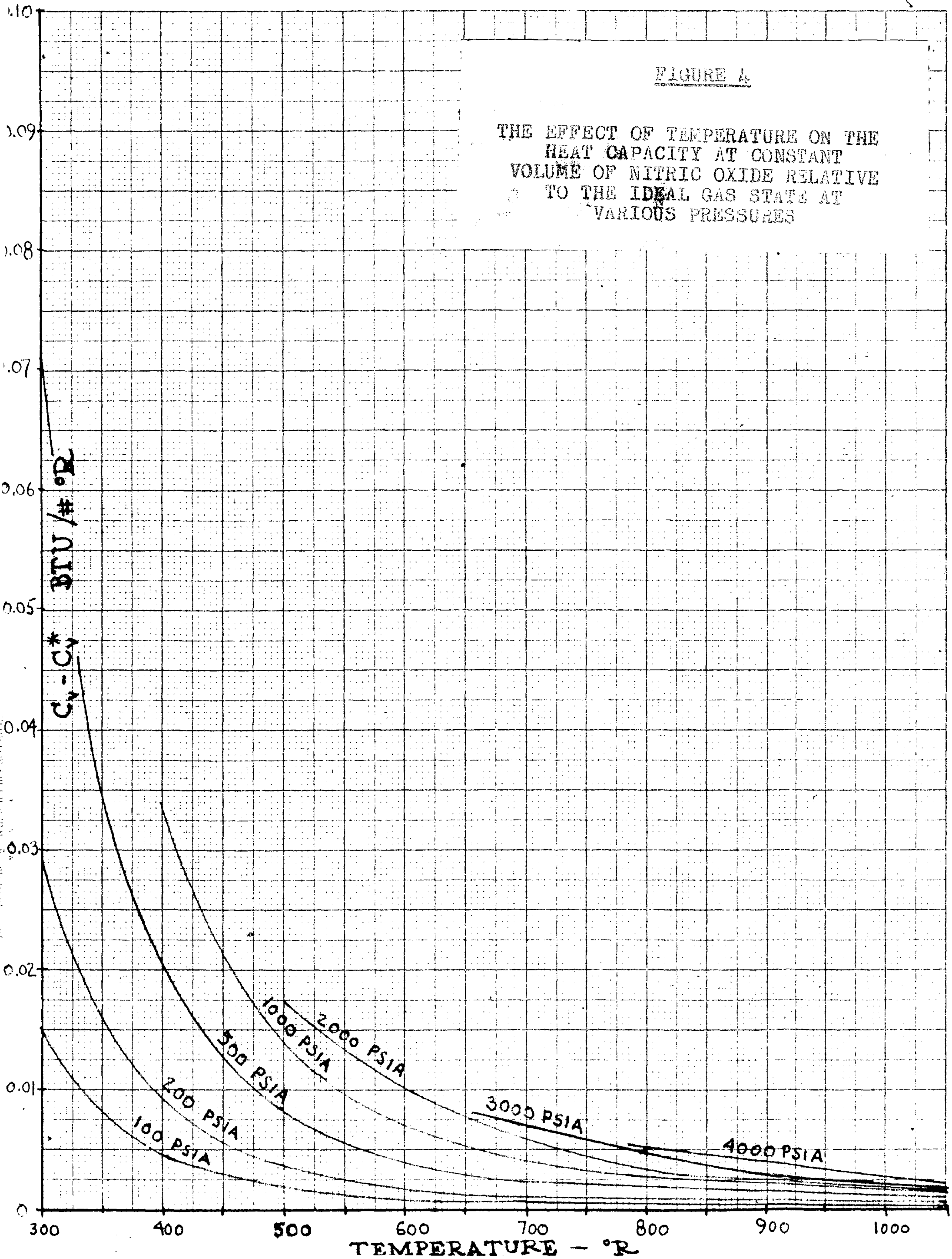



FIGURE 3

THE EFFECT OF PRESSURE ON THE HEAT CAPACITY AT CONSTANT VOLUME OF NITRIC OXIDE RELATIVE TO THE IDEAL GAS STATE AT VARIOUS TEMPERATURES

FIGURE 4

THE EFFECT OF TEMPERATURE ON THE HEAT CAPACITY AT CONSTANT VOLUME OF NITRIC OXIDE RELATIVE TO THE IDEAL GAS STATE AT VARIOUS PRESSURES



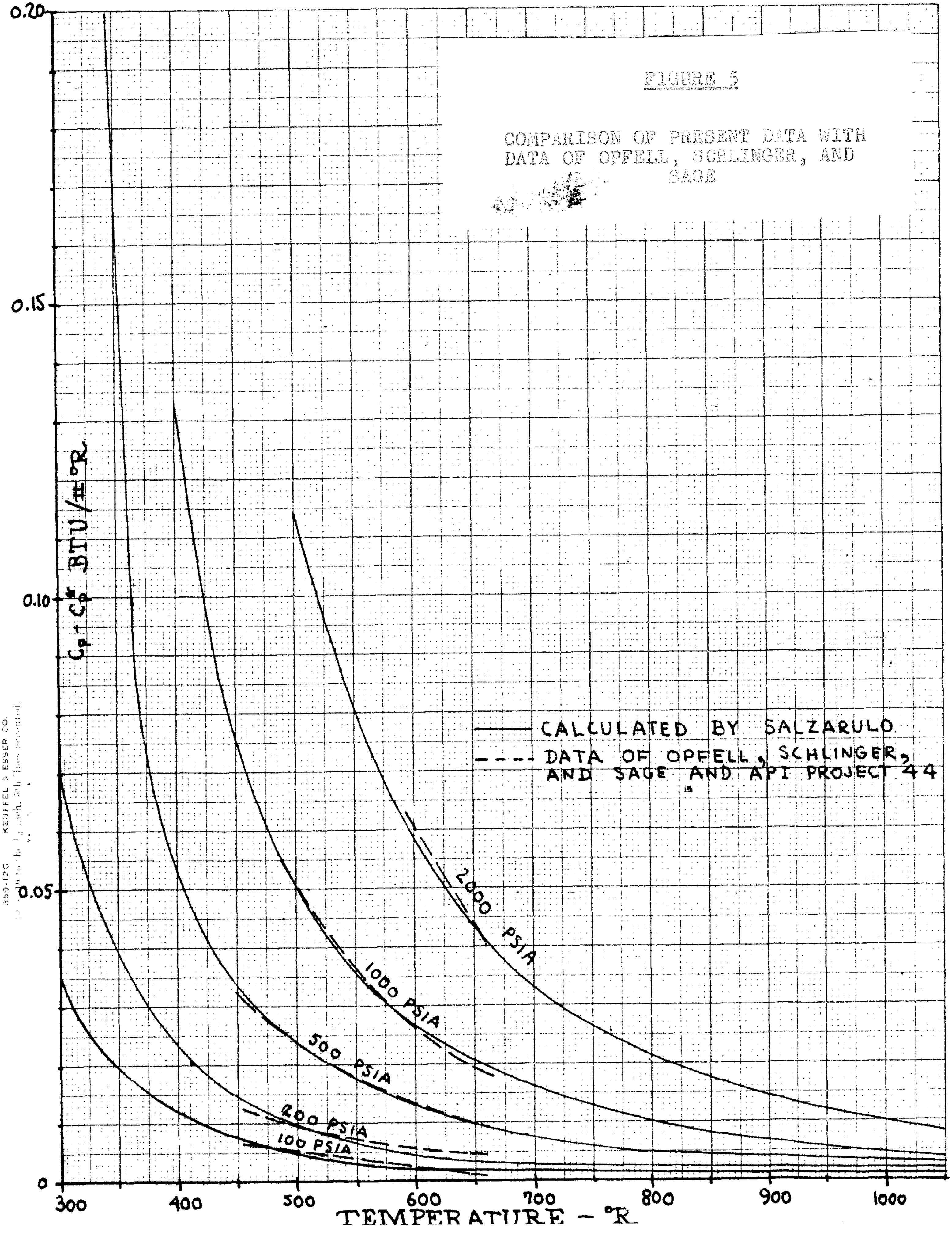


FIGURE 5
COMPARISON OF PRESENT DATA WITH DATA OF OPFELL, SCHLINGER, AND SAGE
CALCULATED BY SALZARULO
DATA OF OPFELL, SCHLINGER, AND SAGE AND API PROJECT 44
2000 PSIA
1000 PSIA
500 PSIA
200 PSIA
100 PSIA
0.20
0.15
0.10
0.05
0
300
400
500
600
700
800
900
1000
TEMPERATURE − °R
$C_p - C_p^*$ BTU/# °R

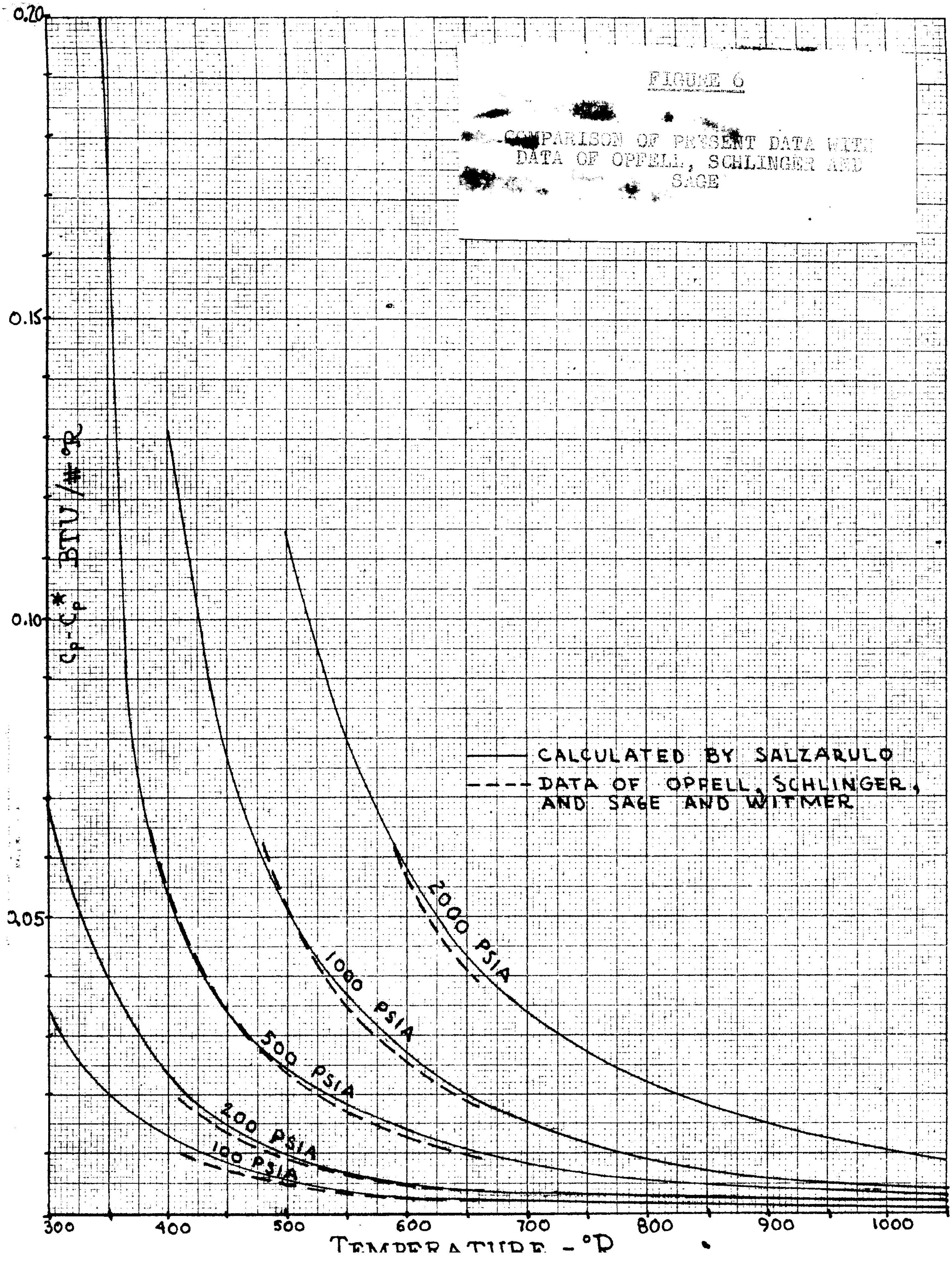



FIGURE 6

COMPARISON OF PRESENT DATA WITH DATA OF OPPELL, SCHLINGER AND SAGE

# SAMPLE CALCULATION → EQUATION E-2

$$P = RT/V + (B_oRT - A_o - C_o/T^2)\frac{1}{V^2} + (bRT - a)\frac{1}{V^3} + (a\alpha)\frac{1}{V^6} + (c/V^3T^2)(1 + \gamma/V^2)(e^{-\gamma/V^2})$$

P : Absolute Pressure, psia

V = Molal Volume, ft.$^3$/# mole

T = Absolute Temperature, °R

= °F + 459.63

e = 2.71828

R = 10.73147, ft$^3$(psi)/#mole °R

$\frac{(1\,ft^3)(psi)}{(\#mole)(°R)} = \frac{0.0061683\ Btu.}{Lb.\ Nitric\ Oxide\ °F}$

$A_o$ = 1630.78 (psi)(ft$^3$)$^2$/(# mole)$^2$

$B_o$ = 0.156389 (ft$^3$)/(# mole)

$C_o$ = 335.286 × 10$^6$ (psi)(ft$^3$)$^2$(°R)$^2$/(# mole)$^2$

a = 14188.61 (psi)(ft$^3$)$^3$/(# mole)$^3$

b = 2.21283 (ft$^3$)$^2$/(# mole)$^2$

c = 915.645 × 10$^6$ (psi)(ft$^3$)$^3$(°R)$^2$/(# mole)$^3$

$\alpha$ = 0.0512202 (ft$^3$)$^3$/(# mole)$^3$

$\gamma$ = 0.5000000 (ft$^3$)$^2$/(# mole)$^2$

T=500°R

| V | RT/V | $\frac{(B_oRT - A_o - C_o/T^2)}{V^2}$ | $\frac{bRT - a}{V^3}$ | $\frac{a\alpha}{V^6}$ | $\frac{c(1+\gamma/V^2)}{V^3T^2e^{\gamma/T^2}}$ | P-psia |
|---|---|---|---|---|---|---|
| 1 | 5365.735 | - 2132.782 | - 2315.150 | 726.7434 | 3332.202 | 4976.749 |
| 2 | 2682.868 | - 533.196 | - 289.394 | 11.3554 | 454.530 | 2326.164 |
| 3 | 1788.578 | - 236.976 | - 85.746 | 0.9969 | 135.448 | 1602.301 |
| 4 | 1341.434 | - 133.299 | - 36.174 | 0.1774 | 57.200 | 1229.339 |

# SAMPLE CALCULATION - EQUATION E-2 (CONTINUED)

## 500.° R

| V | RT/V | $\frac{B_oRT - A_o - C_o/T^2}{V^2}$ | $\frac{bRT-a}{V^3}$ | $\frac{a\alpha}{V^6}$ | $\frac{c(1+\gamma/V^2)}{V^3T^2e^{\gamma/T^2}}$ | P-psia |
|---|---|---|---|---|---|---|
| 5 | 1073.147 | - 85.311 | - 18.521 | 0.0465 | 29.294 | 998.657 |
| 6 | 894.289 | - 59.244 | - 10.718 | 0.0155 | 16.955 | 841.297 |
| 7 | 766.534 | - 43.526 | - 6.750 | 0.0062 | 10.678 | 726.941 |
| 8 | 670.717 | - 33.325 | - 4.522 | 0.0028 | 7.153 | 640.027 |
| 9 | 596.193 | - 26.331 | - 3.176 | 0.0014 | 5.024 | 571.712 |
| 10 | 536.574 | - 21.328 | - 2.315 | 0.0007 | 3.663 | 516.594 |
| 15 | 357.716 | - 9.479 | - 0.686 | 0.0001 | 1.085 | 348.636 |
| 20 | 268.287 | - 5.332 | - 0.289 | 0.0000 | 0.458 | 263.123 |
| 100 | 53.657 | - 0.213 | - 0.002 | 0.0000 | 0.004 | 53.445 |
| 1000 | 5.366 | - 0.002 | - 0.000 | 0.0000 | 0.000 | 5.364 |

# SAMPLE CALCULATION → EQUATION E-11

$$(\delta P/\delta T)_v^2 = \left[R/V + B_0 R/V^2 + 2\,C_0/V^2T^3 + bR/V^3 - (2c/V^3T^3)(1+\gamma/V^2)(e^{-\gamma/V^2})\right]^2$$

| V | $R/V$ | $B_0R/V^2$ | $2C_0/V^2T^3$ | $bR/V^3$ | $-(2c/V^3T^3)(1+\frac{\gamma}{V^2})(e^{-\frac{\gamma}{V^2}})$ | $\left(\frac{\delta P}{\delta T}\right)_v$ | $\left(\frac{\delta P}{\delta T}\right)_v^2$ |
|---|---|---|---|---|---|---|---|
| 1 | 10.73147 | 1.678284 | 5.364576 | 23.746920 | -13.328810 | 28.192441 | 794.81372 |
| 2 | 5.36574 | 0.419570 | 1.341144 | 2.968365 | - 1.818122 | 8.276693 | 68.50364 |
| 3 | 3.57716 | 0.186476 | 0.596064 | 0.879516 | - 0.541797 | 4.697415 | 22.06571 |
| 4 | 2.68287 | 0.104893 | 0.335286 | 0.371046 | - 0.228802 | 3.265290 | 10.66212 |
| 5 | 2.14629 | 0.067131 | 0.214583 | 0.189975 | - 0.117179 | 2.500804 | 6.25402 |
| 6 | 1.78858 | 0.046619 | 0.149016 | 0.109939 | - 0.067819 | 2.026334 | 4.10603 |
| 7 | 1.53307 | 0.034251 | 0.109481 | 0.069233 | - 0.042710 | 1.703322 | 2.90131 |
| 8 | 1.34143 | 0.026223 | 0.083822 | 0.046381 | - 0.028613 | 1.469246 | 2.15868 |
| 9 | 1.19239 | 0.020720 | 0.066229 | 0.032575 | - 0.020096 | 1.291813 | 1.66878 |
| 10 | 1.07315 | 0.016783 | 0.053646 | 0.023747 | - 0.014650 | 1.152672 | 1.32865 |
| 15 | 0.71543 | 0.007459 | 0.023843 | 0.007036 | - 0.004341 | 0.749428 | 0.56164 |
| 20 | 0.53657 | 0.004196 | 0.013411 | 0.002968 | - 0.000183 | 0.556966 | 0.31021 |
| 100 | 0.10731 | 0.000168 | 0.000536 | 0.000024 | - 0.000015 | 0.108028 | 0.01167 |
| 1000 | 0.01073 | 0.000002 | 0.000005 | 0.000000 | - 0.000000 | 0.010739 | 0.00012 |

# SAMPLE CALCULATION - EQUATION E-12

$$\left(\frac{\delta P}{\delta V}\right)_T = -\frac{RT}{V^2} - \left(\frac{2}{V^3}\right)\left(B_0RT - A_0 - \frac{C_0}{T^2}\right) - \left(\frac{3}{V^4}\right)(bRT - a) - \frac{6a\alpha}{V^7} + \left(\frac{c}{T^2}\right)\left(e^{-\frac{\gamma}{V^2}}\right)\left(-\frac{3}{V^4} - \frac{3\gamma}{V^6} + \frac{2\gamma^2}{V^8}\right)$$

| $V$ | $-\frac{RT}{V^2}$ | $-\frac{2}{V^3}\left[B_0RT - A_0 - \frac{C_0}{T^2}\right]$ | $-\frac{3}{V^4}\left[bRT - a\right]$ | $-\frac{6a\alpha}{V^7}$ | $\frac{c}{T^2}\left(e^{-\frac{\gamma}{V^2}}\right)\left[-\frac{3}{V^4} - \frac{3\gamma}{V^6} - \frac{2\gamma^2}{V^8}\right]$ | $\left(\frac{\delta P}{\delta V}\right)_T$ |
|---|---|---|---|---|---|---|
| 1 | -5365.735 | 4265.564 | 6945.450 | -4360.460 | -8885.873 | -7401.055 |
| 2 | -1341.434 | 533.196 | 434.091 | - 34.066 | - 737.712 | - 1145.926 |
| 3 | - 596.193 | 157.984 | 85.746 | - 1.994 | - 135.185 | - 489.642 |
| 4 | - 335.358 | 66.649 | 27.131 | - 0.266 | - 42.873 | - 284.718 |
| 5 | - 214.629 | 34.125 | 11.113 | - 0.056 | - 17.572 | - 187.020 |
| 6 | - 149.048 | 19.750 | 5.359 | - 0.016 | - 8.476 | - 132.433 |
| 7 | - 109.505 | 12.436 | 2.893 | - 0.005 | - 4.576 | - 98.757 |
| 8 | - 83.840 | 8.331 | 1.696 | - 0.002 | - 2.683 | - 76.497 |
| 9 | - 66.244 | 5.851 | 1.059 | - 0.001 | - 1.675 | - 61.009 |
| 10 | - 53.657 | 4.266 | 0.695 | - 0.000 | - 1.099 | - 49.796 |
| 15 | - 23.848 | 1.264 | 0.137 | - 0.000 | - 0.217 | - 22.664 |
| 20 | - 13.414 | 0.533 | 0.043 | - 0.000 | - 0.069 | - 12.906 |
| 100 | - 0.537 | 0.004 | 0.000 | - 0.000 | - 0.000 | - 0.532 |
| 1000 | - 0.005 | 0.000 | 0.000 | - 0.000 | - 0.000 | - 0.005 |

# SAMPLE CALCULATION – EQUATION E-20

$$(c_v - c_v^*) = \frac{6c}{T^3}\left[\frac{e^{-\frac{\gamma}{V^2}}}{\gamma} + \frac{e^{-\frac{\gamma}{V^2}}}{2V^2} + \frac{C_0}{cV}\right] - \frac{6c}{\gamma T^3}$$

| $V$ | $\frac{6c}{T^3}\left[\frac{e^{-\frac{\gamma}{V^2}}}{\gamma} + \frac{e^{-\frac{\gamma}{V^2}}}{2V^2} + \frac{C_0}{cV}\right]$ | $-\frac{6c}{\gamma T^3}$ | $c_v - c_v^*$ |
|---|---|---|---|
| 1 | 82.737779 | −87.90192 | −5.164141 |
| 2 | 90.468362 | −87.90192 | 2.566442 |
| 3 | 90.825955 | −87.90192 | 2.924035 |
| 4 | 90.552084 | −87.90192 | 2.650164 |
| 5 | 90.241733 | −87.90192 | 2.339813 |
| 6 | 89.973786 | −87.90192 | 2.071876 |
| 7 | 89.752572 | −87.90192 | 1.850652 |
| 8 | 89.570276 | −87.90192 | 1.668356 |
| 9 | 89.418799 | −87.90192 | 1.516879 |
| 10 | 89.291588 | −87.90192 | 1.389668 |
| 15 | 88.877143 | −87.90192 | 0.975223 |
| 20 | 88.651684 | −87.90192 | 0.749764 |
| 100 | 88.060658 | −87.90192 | 0.158738 |
| 1000 | 87.918037 | −87.90192 | 0.016117 |

# SAMPLE CALCULATION - EQUATION E-21.

$$(c_p - c_p^*) = (c_p - c_v) + (c_v - c_v^*) - R = -T\frac{(\delta P/\delta T)_v^2}{(\delta P/\delta V)_T} + (c_v - c_v^*) - R$$

| $V$ | $(\delta P/\delta T)_v^2$ | $(\delta P/\delta V)_T$ | $-T\frac{(\delta P/\delta T)_v^2}{(\delta P/\delta V)_T}$ | $(c_v - c_v^*)$ | $-R$ | $(c_p - c_p^*)$ $\frac{ft^3 - psi}{\#mole\ ^\circ R}$ | $(c_p - c_p^*)$ $\frac{Btu}{\#\ ^\circ F}$ | $p$ psia |
|---|---|---|---|---|---|---|---|---|
| 1 | 794.81372 | -7401.055 | 53 69598 | -5.164191 | -10.73147 | 37.800364 | 0.233164 | 4976.749 |
| 2 | 68 50364 | -1145.926 | 29.89007 | 2.566442 | -10.73147 | 21 725047 | 0.134007 | 2326.164 |
| 3 | 22.06571 | - 489.642 | 22 53250 | 2.924035 | -10.73147 | 14 725069 | 0 090828 | 1602.301 |
| 4 | 10.66212 | - 284 718 | 18.72402 | 2.650164 | -10.73147 | 10.642716 | 0.065647 | 1229 339 |
| 5 | 6 25402 | - 187 020 | 16. 72017 | 2.339813 | -10.73.147 | 8.328512 | 0.051373 | 998.657 |
| 6 | 4.10603 | - 132.433 | 15. 50229 | 2.071876 | -10.73147 | 6.842695 | 0 042208 | 841.297 |
| 7 | 2.90131 | - 98.757 | 14 68906 | 1.850652 | -10.73147 | 5.808242 | 0.035827 | 726.941 |
| 8 | 2.15868 | - 76.497 | 14.10953 | 1.668356 | -10.73147 | 5.046415 | 0.031128 | 640.027 |
| 9 | 1.66878 | - 61.009 | 13.67644 | 1.516879 | -10.73147 | 4.461844 | 0.027522 | 571.712 |
| 10 | 1 32865 | - 49 796 | 13.34086 | 1 389668 | -10.73147 | 3.999054 | 0.024667 | 516.594 |
| 15 | 0.56164 | - 22.664 | 12 39079 | 0 975223 | -10.73147 | 2.634544 | 0.016251 | 348.636 |
| 20 | 0 31021 | - 12.906 | 12 01769 | 0 749764 | -10.73147 | 2 035987 | 0.012559 | 263.123 |
| 100 | 0.01167 | - 0 532 | 10.96093 | 0.158738 | -10.73147 | 0.388199 | 0.002395 | 53.445 |
| 1000 | 0 00012 | - 0 005 | 10 75415 | 0 016117 | -10.73147 | 0.038798 | 0.000239 | 5.364 |

# TABLE I

## CALCULATED DATA - T=300°R

| V | P | $C_p - C_v$ | $C_v - C_v^*$ | $-R$ | $C_p - C_p^*$ | $C_p - C_p^*$ | $C_v - C_v^*$ |
|---|---|---|---|---|---|---|---|
| ft³/#mole | psia | ft³-psi / #mole °R | ft³-psi / #mole °R | ft³-psi / #mole °R | ft³-psi / #mole °R | Btu / # °F | Btu / # °F |
| 1 | 1285.08 | 0.112378 | -23.90806 | -10.73147 | -34.527152 | -0.21297 | -0.147470 |
| 2 | 787.43 | 36.684813 | 11.88168 | -10.73147 | 37.835023 | 0.23338 | 0.073290 |
| 3 | 649.55 | 62.975280 | 13.53720 | -10.73147 | 65.781010 | 0.40576 | 0.083502 |
| 4 | 550.25 | 46.444161 | 12.26928 | -10.73147 | 47.981971 | 0.29597 | 0.075681 |
| 5 | 474.66 | 36.981231 | 10.83247 | -10.73147 | 37.082231 | 0.22873 | 0.066818 |
| 6 | 416.18 | 31.258083 | 9.59197 | -10.73147 | 30.118583 | 0.18578 | 0.059166 |
| 7 | 369.96 | 27.500762 | 8.56783 | -10.73147 | 26.337122 | 0.16246 | 0.052849 |
| 8 | 332.68 | 24.869703 | 7.72387 | -10.73147 | 21.862103 | 0.13485 | 0.047643 |
| 9 | 302.07 | 22.933931 | 7.02259 | -10.73147 | 19.225051 | 0.11859 | 0.043317 |
| 10 | 276.53 | 21.453840 | 6.43365 | -10.73147 | 17.156020 | 0.10582 | 0.039685 |
| 15 | 193.98 | 17.372846 | 4.51492 | -10.73147 | 11.156296 | 0.06882 | 0.027849 |
| 20 | 149.23 | 15.927404 | 3.47113 | -10.73147 | 8.667064 | 0.05346 | 0.021411 |

## TABLE. I

### CALCULATED DATA – T = 400°R

| V ft³/#mole | P psia | $C_p - C_v$ ft³-psi/#mole °R | $C_v - C_v^*$ ft³-psi/#mole °R | −R ft³-psi/#mole °R | $C_p - C_p^*$ ft³-psi/#mole °R | $C_p - C_p^*$ Btu/# °F | $C_v - C_v^*$ Btu/# °F |
|---|---|---|---|---|---|---|---|
| 1 | 2481.06 | 72.006124 | −10.08622 | −10.73147 | 51.188434 | 0.31575 | −0.062215 |
| 2 | 1517.87 | 39.679283 | 5.01258 | −10.73147 | 33.960390 | 0.20948 | 0.030919 |
| 3 | 1130.36 | 31.089988 | 5.71100 | −10.73147 | 26.069518 | 0.16080 | 0.035227 |
| 4 | 898.48 | 24.492308 | 5.17610 | −10.73147 | 18.936938 | 0.11681 | 0.031928 |
| 5 | 744.62 | 21.050611 | 4.56994 | −10.73147 | 14.889081 | 0.09184 | 0.028189 |
| 6 | 635.37 | 18.962653 | 4.04661 | −10.73147 | 12.277793 | 0.07573 | 0.024961 |
| 7 | 553.90 | 17.568347 | 3.61455 | −10.73147 | 10.451427 | 0.06447 | 0.022296 |
| 8 | 490.86 | 16.573991 | 3.25851 | −10.73147 | 9.101031 | 0.05614 | 0.020099 |
| 9 | 440.66 | 15.830124 | 2.96265 | −10.73147 | 8.061304 | 0.04973 | 0.018275 |
| 10 | 399.74 | 15.253227 | 2.71419 | −10.73147 | 7.235945 | 0.04463 | 0.016742 |
| 15 | 272.90 | 13.615256 | 1.90473 | −10.73147 | 4.788516 | 0.02954 | 0.011749 |
| 20 | 207.12 | 12.993322 | 1.46438 | −10.73147 | 3.726232 | 0.02299 | 0.009033 |

## TABLE I

CALCULATED DATA $T = 600^\circ R$

| V $ft^3$/#mole | P psia | $C_p - C_v$ $\frac{ft^3\text{-psi}}{\#mole\ ^\circ R}$ | $C_v - C_v^*$ $\frac{ft^3\text{-psi}}{\#mole\ ^\circ R}$ | R $\frac{ft^3\text{-psi}}{\#mole\ ^\circ R}$ | $C_p - C_p^*$ $\frac{ft^3\text{-psi}}{\#mole\ ^\circ R}$ | $C_p - C_p^*$ $\frac{Btu}{\#\ ^\circ F}$ | $C_v - C_v^*$ $\frac{Btu}{\#\ ^\circ F}$ |
|---|---|---|---|---|---|---|---|
| 1 | 7984.04 | 42.537361 | -2.988507 | -10.73147 | 28.817384 | 0.177750 | -0.0184343 |
| 2 | 3165.10 | 24.822341 | 1.485210 | -10.73147 | 15.576081 | 0.096078 | 0.0091612 |
| 3 | 2070.76 | 18.775080 | 1.692150 | -10.73147 | 9.735760 | 0.060053 | 0.0104384 |
| 4 | 1553.35 | 16.180990 | 1.533660 | -10.73147 | 6.983180 | 0.043074 | 0.0094601 |
| 5 | 1246.44 | 14.804333 | 1.354059 | -10.73147 | 5.426922 | 0.033475 | 0.0083522 |
| 6 | 1042.01 | 13.965795 | 1.198997 | -10.73147 | 4.433322 | 0.027346 | 0.0073958 |
| 7 | 895.70 | 13.406249 | 1.070980 | -10.73147 | 3.745759 | 0.023105 | 0.0066061 |
| 8 | 785.65 | 13.009135 | 0.965484 | -10.73147 | 3.243149 | 0.020005 | 0.0059554 |
| 9 | 699.80 | 12.711425 | 0.877824 | -10.73147 | 2.857779 | 0.017628 | 0.0054147 |
| 10 | 630.94 | 12.481991 | 0.804206 | -10.73147 | 2.554727 | 0.015758 | 0.0049606 |
| 15 | 423.12 | 11.836189 | 0.564365 | -10.73147 | 1.669084 | 0.010295 | 0.0034812 |
| 20 | 318.38 | 11.576930 | 0.433892 | -10.73147 | 1.279352 | 0.007891 | 0.0026764 |

# TABLE I

## CALCULATED DATA T = 700 °R

| V<br>ft³/# mole | P<br>psia | $c_p - c_v$<br>ft³-psi / # mole °R | $c_v - c_v^*$<br>ft³-psi / # mole °R | −R<br>ft³-psi / # mole °R | $c_p - c_p^*$<br>ft³-psi / # mole °R | $c_p - c_p^*$<br>Btu / # °F | $c_v - c_v^*$<br>Btu / # °F |
|---|---|---|---|---|---|---|---|
| 1 | 11232.86 | 36.124714 | −1.881975 | −10.73147 | 23.511269 | 0.145023 | −0.0116093 |
| 2 | 4018.49 | 20.948570 | 0.935293 | −10.73147 | 11.152393 | 0.068791 | 0.0057692 |
| 3 | 2537.58 | 16.700868 | 1.065611 | −10.73147 | 7.035009 | 0.043394 | 0.0065730 |
| 4 | 1874.14 | 14.771469 | 0.965804 | −10.73147 | 5.005803 | 0.030877 | 0.0059574 |
| 5 | 1494.26 | 13.744358 | 0.852702 | −10.73147 | 3.865590 | 0.023844 | 0.0052597 |
| 6 | 1240.27 | 13.118146 | 0.755054 | −10.73147 | 3.141730 | 0.019379 | 0.0046574 |
| 7 | 1062.43 | 12.700491 | 0.674437 | −10.73147 | 2.643458 | 0.016306 | 0.0041601 |
| 8 | 929.60 | 12.403759 | 0.608002 | −10.73147 | 2.280291 | 0.014066 | 0.0037503 |
| 9 | 826.50 | 12.182869 | 0.552799 | −10.73147 | 2.004198 | 0.012362 | 0.0034098 |
| 10 | 744.11 | 12.012390 | 0.506440 | −10.73147 | 1.787360 | 0.011025 | 0.0031239 |
| 15 | 497.01 | 11.534660 | 0.355403 | −10.73147 | 1.158593 | 0.007147 | 0.0021922 |
| 20 | 373.29 | 11.339621 | 0.273238 | −10.73147 | 0.881389 | 0.005437 | 0.0016854 |

# TABLE I

**CALCULATED DATA T=1000°R**

| V $ft^3$/#mole | P psia | $c_p - c_v$ $\frac{ft^3\text{-psi}}{\#mole\ ^\circ R}$ | $c_v - c_v^*$ $\frac{ft^3\text{-psi}}{\#mole\ ^\circ R}$ | $-R$ $\frac{ft^3\text{-psi}}{\#mole\ ^\circ R}$ | $c_p - c_p^*$ $\frac{ft^3\text{-psi}}{\#mole\ ^\circ R}$ | $c_p - c_p^*$ $\frac{Btu}{\#\ ^\circ F}$ | $c_v - c_v^*$ $\frac{Btu}{\#\ ^\circ F}$ |
|---|---|---|---|---|---|---|---|
| 1 | 21561.79 | 27.223753 | -0.645518 | -10.73147 | 15.846765 | 0.097748 | -0.0039817 |
| 2 | 6613.57 | 16.355039 | 0.320805 | -10.73147 | 5.944374 | 0.036667 | 0.0019788 |
| 3 | 3934.05 | 13.795751 | 0.365504 | -10.73147 | 3.429785 | 0.021156 | 0.0022545 |
| 4 | 2828.71 | 12.822830 | 0.331271 | -10.73147 | 2.422631 | 0.014944 | 0.0020434 |
| 5 | 2218.62 | 12.284673 | 0.292477 | -10.73147 | 1.845680 | 0.011385 | 0.0018041 |
| 6 | 1829.09 | 11.958840 | 0.258483 | -10.73147 | 1.486353 | 0.009168 | 0.0015975 |
| 7 | 1557.74 | 11.742221 | 0.231332 | -10.73147 | 1.242083 | 0.007662 | 0.0014269 |
| 8 | 1357.40 | 11.588619 | 0.208545 | -10.73147 | 1.065694 | 0.006574 | 0.0012864 |
| 9 | 1190.10 | 11.474428 | 0.189610 | -10.73147 | 0.932568 | 0.005752 | 0.0011696 |
| 10 | 1080.74 | 11.386384 | 0.173709 | -10.73147 | 0.828623 | 0.005111 | 0.0010715 |
| 15 | 717.26 | 11.140331 | 0.121903 | -10.73147 | 0.530764 | 0.003274 | 0.0007519 |
| 20 | 537.16 | 11.035881 | 0.093721 | -10.73147 | 0.398132 | 0.002456 | 0.0005781 |

# TABLE I

## CALCULATED DATA T=1800°R

| V ($ft^3$/#mole) | P (psia) | $c_p - c_v$ ($\frac{ft^3\text{-}psi}{\#mole\ °R}$) | $c_v - c_v^*$ ($\frac{ft^3\text{-}psi}{\#mole\ °R}$) | $-R$ ($\frac{ft^3\text{-}psi}{\#mole\ °R}$) | $c_p - c_p^*$ ($\frac{ft^3\text{-}psi}{\#mole\ °R}$) | $c_p - c_p^*$ ($\frac{Btu}{\#\ °F}$) | $c_v - c_v^*$ ($\frac{Btu}{\#\ °F}$) |
|---|---|---|---|---|---|---|---|
| 1 | 47827.85 | 22.061545 | -0.110686 | -10.73147 | 11.219389 | 0.0692056 | -0.00068274 |
| 2 | 13306.50 | 13.541319 | 0.055008 | -10.73147 | 2.864857 | 0.0176711 | 0.00033930 |
| 3 | 7565.17 | 12.035484 | 0.062672 | -10.73147 | 1.366686 | 0.0084301 | 0.00038658 |
| 4 | 5324.18 | 11.540280 | 0.056802 | -10.73147 | 0.865612 | 0.0053394 | 0.00035037 |
| 5 | 4127.03 | 11.313554 | 0.050150 | -10.73147 | 0.632234 | 0.0038998 | 0.00030934 |
| 6 | 3377.99 | 11.186432 | 0.044407 | -10.73147 | 0.499369 | 0.0030803 | 0.00027392 |
| 7 | 2863.11 | 11.105453 | 0.039666 | -10.73147 | 0.413649 | 0.0025515 | 0.00024467 |
| 8 | 2486.49 | 11.049296 | 0.035759 | -10.73147 | 0.353585 | 0.0021810 | 0.00022057 |
| 9 | 2198.56 | 11.008025 | 0.032512 | -10.73147 | 0.309067 | 0.0019064 | 0.00020054 |
| 10 | 1971.06 | 10.976342 | 0.029785 | -10.73147 | 0.274657 | 0.0016942 | 0.00018373 |
| 15 | 1301.36 | 10.887477 | 0.020902 | -10.73147 | 0.176909 | 0.0010912 | 0.00012893 |
| 20 | 972.36 | 10.847483 | 0.016070 | -10.73147 | 0.132083 | 0.0008147 | 0.00009913 |

# TABLE I

## CALCULATED DATA T=2500°R

| V ft³/#mole | P psia | $C_p - C_v$ ft³-psi / #mole °R | $C_v - C_v^*$ ft³-psi / #mole °R | $-R$ ft³-psi / #mole °R | $C_p - C_p^*$ ft³-psi / #mole °R | $C_p - C_p^*$ Btu / # °F | $C_v - C_v^*$ Btu / # °F |
|---|---|---|---|---|---|---|---|
| 1 | 75,378.68 | 18.923265 | -0.041313 | -10.73147 | 8.150482 | 0.0502754 | -0.00025483 |
| 2 | 19,719.04 | 12.060807 | 0.020531 | -10.73147 | 1.349869 | 0.0083264 | 0.00012664 |
| 3 | 10,901.62 | 11.009693 | 0.023392 | -10.73147 | 0.301615 | 0.0018605 | 0.00014429 |
| 4 | 7572.51 | 10.914734 | 0.021201 | -10.73147 | 0.204465 | 0.0012612 | 0.00013078 |
| 5 | 5828.84 | 10.857107 | 0.018719 | -10.73147 | 0.144356 | 0.0008904 | 0.00011546 |
| 6 | 4751.06 | 10.836852 | 0.016575 | -10.73147 | 0.121957 | 0.0007523 | 0.00010224 |
| 7 | 4016.07 | 10.827512 | 0.014805 | -10.73147 | 0.110847 | 0.0006837 | 0.00009132 |
| 8 | 3481.35 | 10.821742 | 0.013347 | -10.73147 | 0.103619 | 0.0006391 | 0.00008233 |
| 9 | 3074.14 | 10.817256 | 0.012135 | -10.73147 | 0.097921 | 0.0006040 | 0.00007485 |
| 10 | 2753.31 | 10.813345 | 0.011117 | -10.73147 | 0.092992 | 0.0005736 | 0.00006858 |
| 15 | 1813.17 | 10.797517 | 0.007802 | -10.73147 | 0.073849 | 0.0004555 | 0.00004812 |
| 20 | 1353.38 | 10.786592 | 0.005998 | -10.73147 | 0.061120 | 0.0003770 | 0.00003700 |

# TABLE II

## VALUES OF THE ISOBARIC HEAT CAPACITY OF NITRIC OXIDE IN THE IDEAL GAS STATE AT VARIOUS TEMPERATURES (1)

| Temperature °F | $C_p^*$ BTU/LB. °F |
|---|---|
| -459.69 | 0 |
| 0 | 0.2386 |
| 32 | 0.2381 |
| 60 | 0.2378 |
| 68 | 0.2377 |
| 77 | 0.2377 |
| 100 | 0.2375 |
| 200 | 0.2378 |
| 300 | 0.2392 |
| 400 | 0.2416 |
| 500 | 0.2446 |
| 600 | 0.2480 |
| 700 | 0.2515 |
| 800 | 0.2550 |
| 900 | 0.2583 |
| 1000 | 0.2615 |
| 1100 | 0.2644 |
| 1200 | 0.2671 |
| 1300 | 0.2697 |
| 1400 | 0.2720 |
| 1500 | 0.2741 |
| 1600 | 0.2760 |
| 1700 | 0.2778 |
| 1800 | 0.2794 |
| 1900 | 0.2809 |
| 2000 | 0.2822 |
| 2100 | 0.2835 |
| 2200 | 0.2846 |

TABLE III

VALUES OF THE ISOBARIC HEAT CAPACITY OF NITRIC OXIDE IN THE IDEAL GAS STATE AT VARIOUS TEMPERATURES (19)

| Temperature °K | $C_p^*$ Cal./g.mole °K |
|---|---|
| 1 | 5.1191 |
| 2 | 6.2642 |
| 3 | 6.7552 |
| 4 | 6.8707 |
| 5 | 6.9079 |
| 10 | 6.9442 |
| 20 | 6.9723 |
| 30 | 7.137 |
| 40 | 7.396 |
| 50 | 7.6176 |
| 60 | 7.743 |
| 70 | 7.801 |
| 80 | 7.798 |
| 90 | 7.762 |
| 100 | 7.7112 |
| 110 | 7.653 |
| 120 | 7.596 |
| 130 | 7.540 |
| 140 | 7.489 |
| 150 | 7.442 |
| 160 | 7.400 |
| 170 | 7.362 |
| 180 | 7.329 |
| 190 | 7.299 |
| 200 | 7.272 |
| 220 | 7.226 |
| 240 | 7.188 |
| 300 | 7.133 |
| 400 | 7.158 |
| 500 | 7.295 |

# NOMENCLATURE

$c_p$ - Specific heat at constant pressure, $Ft^3$-PSI/Lb mol $^oR$

$C_p$ - Specific heat at constant pressure, BTU/Lb. $^oR$

$c_p^*$ - Specific heat at constant pressure for a gas in the ideal gas state, $Ft^3$-PSI/Lb mol $^oR$

$C_p^*$ - Specific heat at constant pressure for a gas in the ideal gas state, BTU/Lb. $^oR$

$c_v$ - Specific heat at constant volume, $Ft^3$-PSI/Lb mol $^oR$

$C_v$ - Specific heat at constant volume, BTU/Lb. $^oR$

$c_v^*$ - Specific heat at constant volume for a gas in the ideal gas state, $Ft^3$-PSI/Lb mol $^oR$

$C_v^*$ - Specific heat at constant volume for a gas in the ideal gas state, BTU/Lb. $^oR$

T - Absolute temperature, $^oR = {^oF} + 459.69$

V - Molal volume, $Ft^3$/Lb. mol.

P - Absolute pressure, Atmospheres

p - Absolute pressure, Lbs. per Square Inch

R - Gas constant, 10.73147 $Ft^3$-PSI/Lb. mol. $^oR$

$A_o$, $B_o$, $C_o$, a, b, c, $\alpha$, $\gamma$ - Constants in the Benedict-Webb-Rubin Equation of State

e - Base of the natural logarithms

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