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SOME THERMODYNAMIC PROPERTIES OF NITRIC OXIDE

December, 1952

CHEMICAL ENGINEERING LABORATORY

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SOME THERMODYNAMIC PROPERTIES OF NITRIC OXIDE

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ABSTRACT

Nitric oxide is an important component of many process gases and a knowledge of the heat and work associated with changes in the state of this compound is of industrial interest. For this reason the thermodynamic properties were established from available volumetric and spectroscopic data.

The thermodynamic properties of nitric oxide were computed by application of the Benedict equation of state and isobaric heat capacities at infinite attenuation for temperatures from -80° to 220°F. and for pressures up to 3000 pounds per square inch. Coefficients for the Benedict equation of state were established from available experimental information concerning the volumetric behavior of nitric oxide. The heat capacity was obtained from published spectroscopic measurements. Specific values of the volume, enthalpy, entropy, and fugacity were calculated for 27 different pressures at each of 11 temperatures.

The results obtained established the thermodynamic properties of nitric oxide throughout the range of temperatures and pressures of primary industrial interest. A sufficient number of states has been included in the tabulation that four point linear interpolation may be used for many applications. Extension of the tabulation to higher temperatures was precluded by lack of experimental data.

(This abstract is intended for publication in a separate section of the journal).

The thermodynamic properties of nitric oxide have not been determined in detail. Briner and coworkers (3) investigated the volumetric behavior at pressures from 450 to 2200 pounds per square inch in the temperature interval between -109° and 48° F. In addition, measurements were recently completed at pressures up to 2500 pounds per square inch for temperatures between 40° and 220° F. (5). These data were in good agreement with determinations of the second virial coefficient made by Johnston and Weimer (7) at temperatures between -243° and 70° F.

The heat capacity of nitric oxide was calculated by Witmer (11) from spectroscopic measurements of Jenkins, Barton, and Mullikin (6). Spencer (10) proposed an analytical expression for the heat capacity but it appears to deviate markedly from Witmer's values and for this reason was not used in the present calculations.

The above mentioned volumetric data served as the basis for the evaluation of the coefficients of the equation of state proposed by Benedict, Webb, and Rubin (1,2), hereinafter referred to as the Benedict equation. Methods devised by Brough (4) with the modifications suggested by Selleck (9) were employed. These methods involved the application of least squares techniques to the estimation of the coefficients yielding the minimum standard error of estimate. Experience has indicated that the Benedict equation, when used with coefficients established by the methods of Brough (4) and Selleck (9), does not necessarily give a satisfactory description of the volumetric behavior of a pure substance beyond the ranges of pressure and temperature for which the coefficients were established.

In the present instance coefficients of the equation of state were based upon volumetric measurements made by Briner (3) and those recently reported by Golding (5). The data of Briner do not agree with the more recent measurements at temperatures in the neighborhood of 40°F. For this reason the results from the former set of measurements at temperatures above -40° F. have been omitted. The experimental data which were used in evaluating the coefficients have been indicated in Figure 1 together with isotherms from the Benedict equation based upon the coefficient recorded in Table I. A value of the universal gas constant of 10.73147 (cu. ft./lb. mole) (lb./sq. inch)/°R. or 1.98588 B.t.u./(lb. mole)/°R. was employed in the calculations. A series of sets of coefficients, such as that shown in Table I, may be obtained for nitric oxide based upon the data of Figure 1 using different values of γ. Values of γ between zero and ten (cu. ft./lb. mole)^2 yield roughly equal deviations from the experimental data (3,5). This behavior is similar to that found for the lighter hydrocarbons (8). The value of γ was taken as 0.5 (cu. ft./lb. mole)^2 because it gave near the minimum standard error of estimate for values of γ between zero and ten.

The coefficients recorded in Table I describe the volumetric behavior of nitric oxide from temperatures of -100° to 220° F. for pressures up to 3000 pounds per square inch with a standard error of estimate of 0.00458 in the compressibility factor. This measure of disagreement ascribes all the error to the pressure and assumes agreement with respect to volume and temperature. These coefficients do not describe adequately the behavior of nitric oxide in the heterogeneous or critical regions. At temperatures of 100° and 200° R. marked disagreement from the estimated behavior of this compound results from the use of

the coefficients listed in Table I.

The expressions for enthalpy, entropy, and fugacity were combined with the relationships for pressure and the isochoric pressure-temperature derivative shown in the first part of Table II in order to obtain desired numerical values of the thermodynamic properties. These calculations were carried out for pressures up to 3000 pounds per square inch at 11 temperatures between -80° and 220° F. The resulting values of volume, enthalpy, entropy, and fugacity which were obtained are recorded in Table III. The values of enthalpy and entropy have been carried to one more significant figure than is justified by the accuracy of the data so that the differences between these quantities for adjacent states might be established with reasonable precision. The heat capacity at infinite attenuation which is shown in Figure 2 was based on the calculations of Witmer (11). In addition, the values of the heat capacity at higher pressures have been included. These data have been established by differentiation of the enthalpy function shown in Table II at constant pressure.

Figure 3 is an enthalpy-pressure diagram for nitric oxide. Temperature and entropy have been included as parameters. A temperature-entropy diagram is shown in Figure 4 with volume, enthalpy, and pressure as parameters. These two diagrams permit most of the thermodynamic processes of industrial interest to be followed with reasonable accuracy.* Figure 5 depicts the compressibility factor as a function of pressure with temperature and entropy as parameters. This diagram when used with the following expression allows more accurate estimation of specific volume than is possible from Figures 3 and 4.

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* Replicas of these diagrams, approximately 8½ inches by 11 inches, may be obtained from the authors for the cost of duplication.

$$V = \frac{V}{M} = Z\left(\frac{RT}{MP}\right) = \frac{ZbT}{P} \qquad (1)$$

However, it is not possible to follow isochoric processes directly upon Figure 5.

The data of Table III and Figures 3, 4, and 5 were based on a reference state for the enthalpy and entropy at a temperature of absolute zero and a pressure of one atmosphere. This basis corresponds to the convention adopted by Rossini (9) and affords a convenient reference for the enthalpy and entropy. Uncertainties in the heat capacities between absolute zero and the lowest temperature in the tables do not introduce errors in the use of the tabular information since the reference states may be chosen arbitrarily. It is believed that the values of pressure, volume, enthalpy, entropy, and fugacity are self-consistent with a standard deviation of not more than 0.1%. However, values of the enthalpy, entropy, and specific volume as a function of state may involve a standard deviation as large as 0.6% as a result of uncertainties in the experimental values of the heat capacity and specific volume.

The self-consistency of the data was established by application of the following expression to a series of random polytropic paths:

$$dH = TdS + VdP \qquad (2)$$

The relationship of fugacity to enthalpy and entropy was checked from the following thermodynamic relation which is applicable to an isothermal change of state:

$$R \ln \frac{f_1}{f_2} = \frac{H_1 - H_2}{T} - (S_1 - S_2) \qquad (3)$$

The statistical estimates of consistency given above were based upon these checks. The information of Table III together with the graphical presentation in Figures 3 and 4 suffices to establish the thermodynamic properties of nitric oxide at pressures up to 3000 pounds per square inch in the temperature interval between -80° and 220° F. It is again emphasized that the extension of the Benedict equation, based upon the coefficients recorded in Table I, to states beyond those covered by the data employed in this study may result in calculated values which deviate markedly from the actual behavior of this compound.

ACKNOWLEDGMENT

This work was supported by the Office of Naval Research. The assistance of W. R. Connell in carrying out the computations with a commercial punched card calculator is acknowledged. Virginia Berry prepared the large scale pressure-enthalpy and temperature-entropy diagrams. W. N. Lacey reviewed the manuscript.

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NOMENCLATURE

α, γ, A, a, B, b, C, c	Coefficients in Benedict equation of state
b	specific gas constant
C_p	heat capacity at constant pressure, B.t.u./(lb.)(°R.)
d	differential operator
e	base of Naperian logarithm
E	internal energy, B.t.u./lb.
f	fugacity, lb./sq. inch
H	enthalpy, B.t.u./lb.
ln	natural logarithm
M	molecular weight
P	absolute pressure, lb./sq. inch
$\underline{R}$	universal gas constant
S	entropy, B.t.u./(lb.)(°R.)
T	absolute temperature, °R.
$\underline{V}$	molal volume, cu. ft./ lb. mole
V	specific volume, cu. ft./lb.
Z	compressibility factor $\frac{PV}{RT}$ or $\frac{P\underline{V}}{\underline{R}T}$
∂	partial differential operator

Subscripts

0	reference state
1,2	particular states of system

Superscript

*	value of property at state of infinite attenuation

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2. Heat Capacity of Nitric Oxide in the Gas Phase

3. Enthalpy-Pressure Diagram for Nitric Oxide

4. Temperature-Entropy Diagram for Nitric Oxide

5. Pressure-Compressibility Factor Diagram for Nitric Oxide

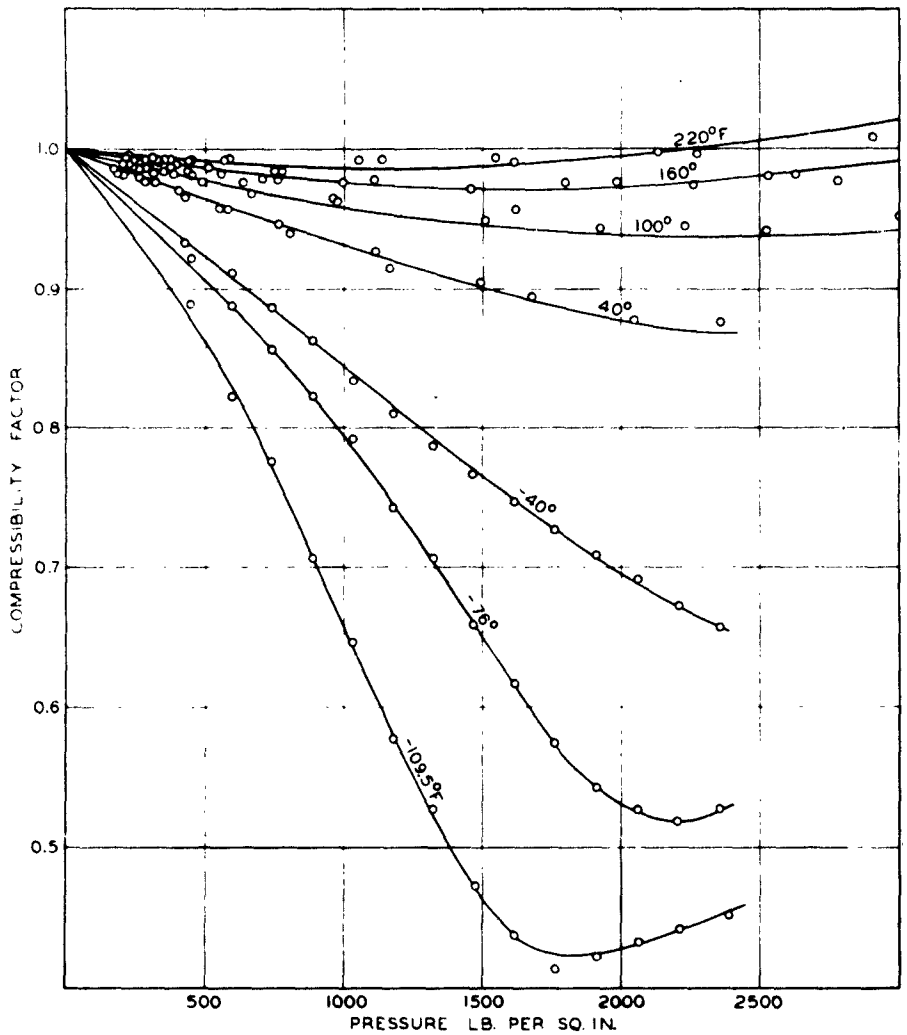

Fig. 1 Experimental Compressibility Factors for Nitric Oxide

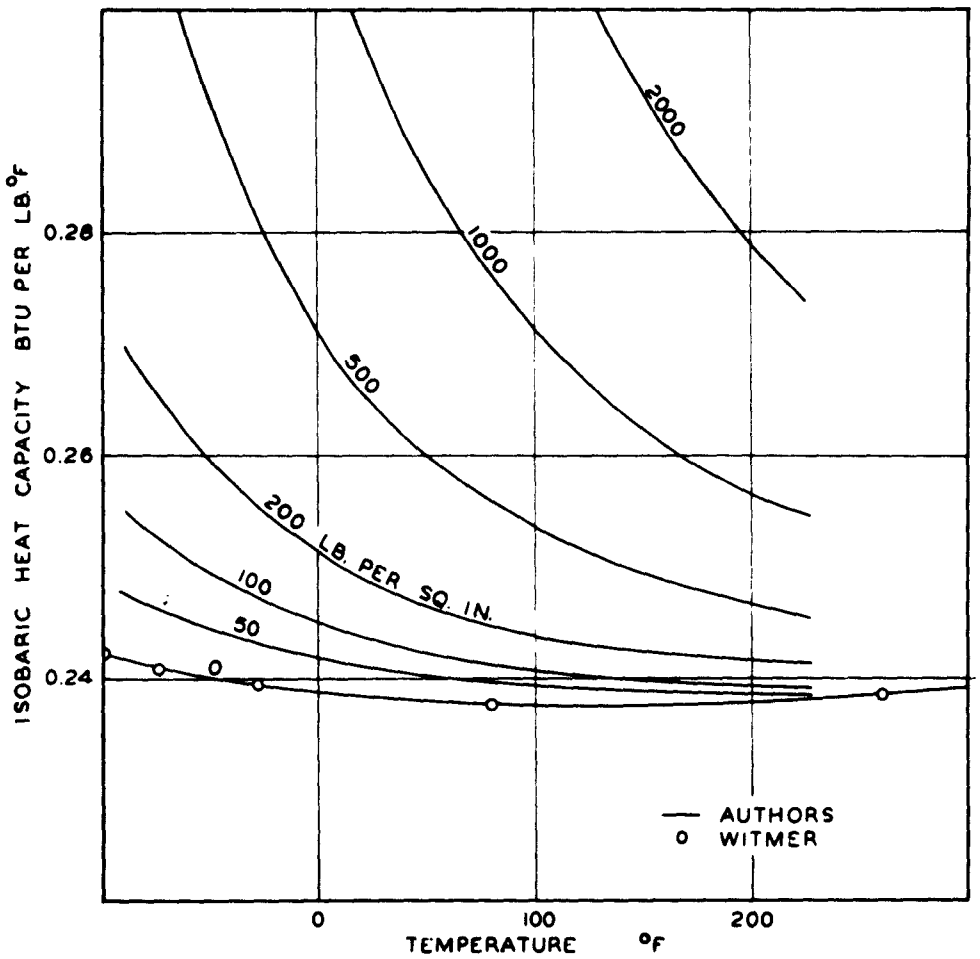

Fig. 2 Heat Capacity of Nitric Oxide in the Gas Phase

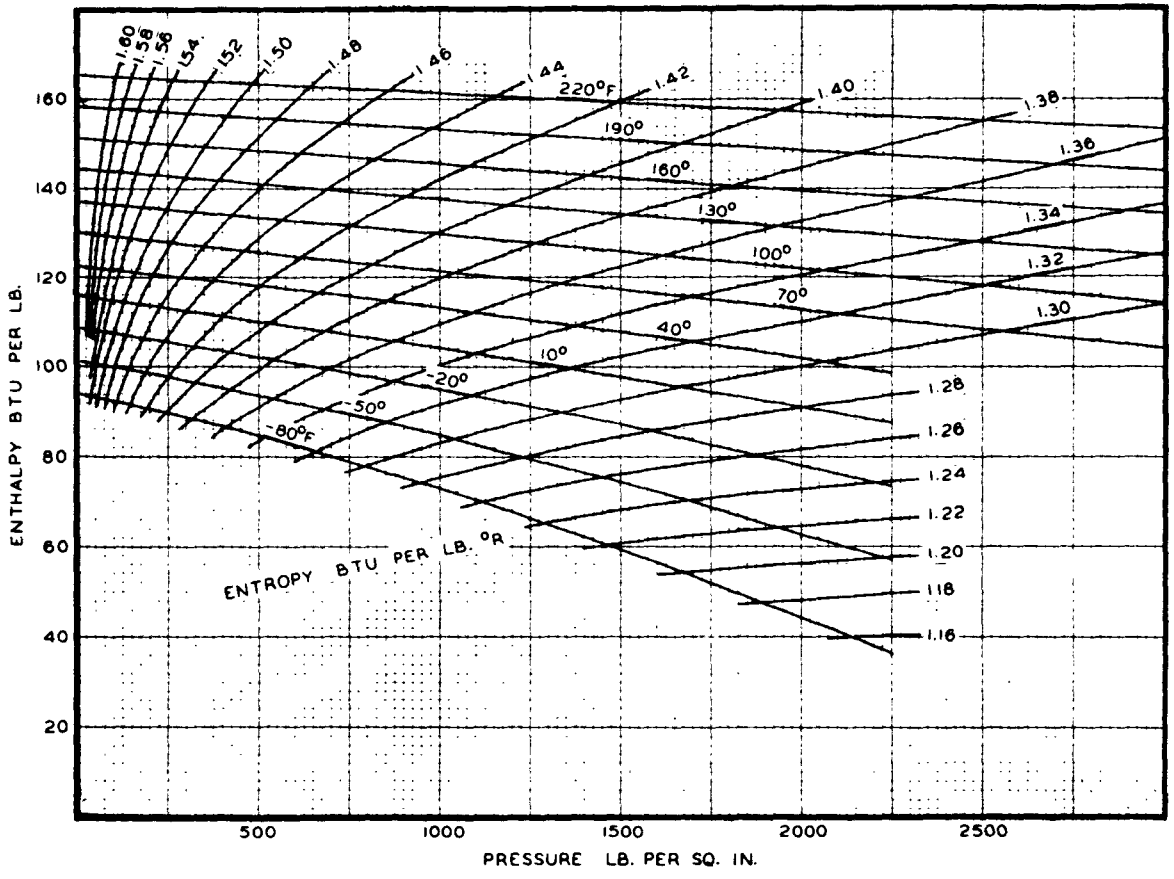

Fig. 3 Enthalpy-Pressure Diagram for Nitric Oxide

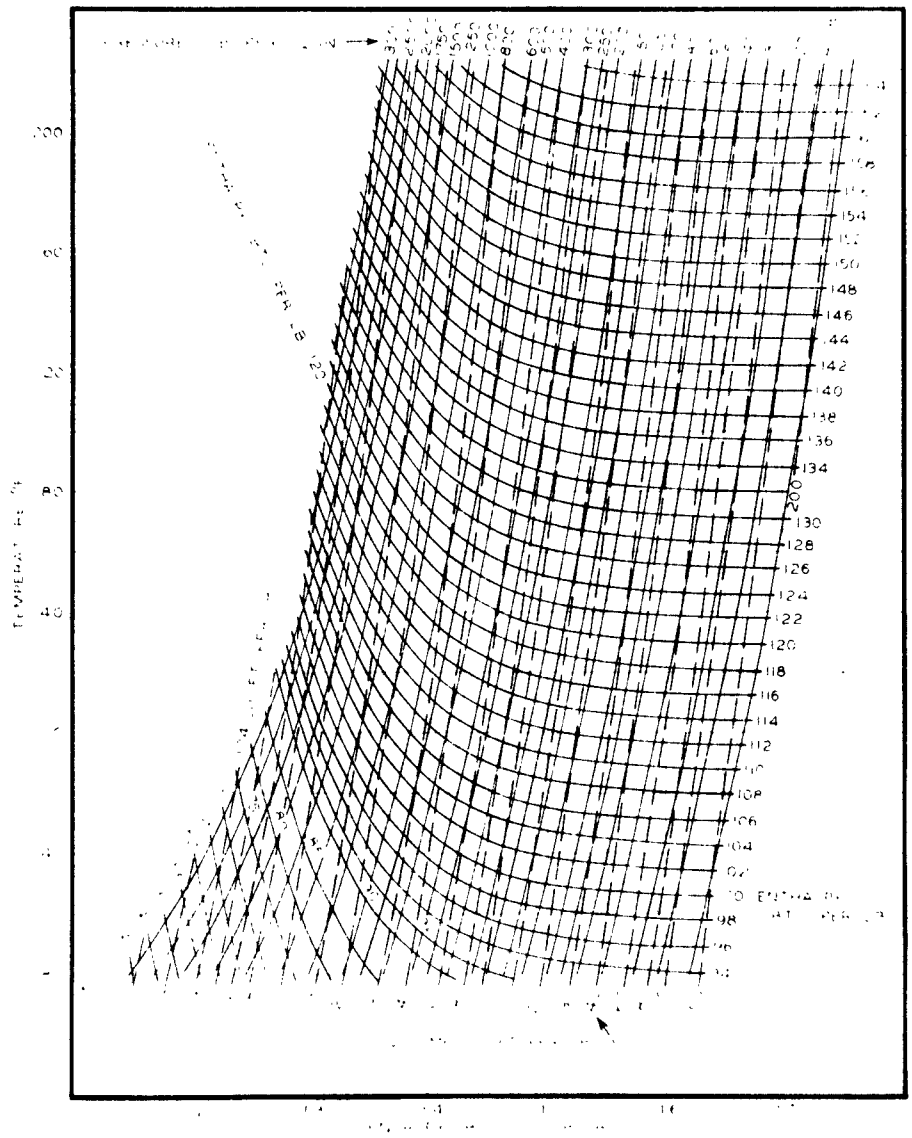

Fig. 4 Temperature-Entropy Diagram for Nitric Oxide

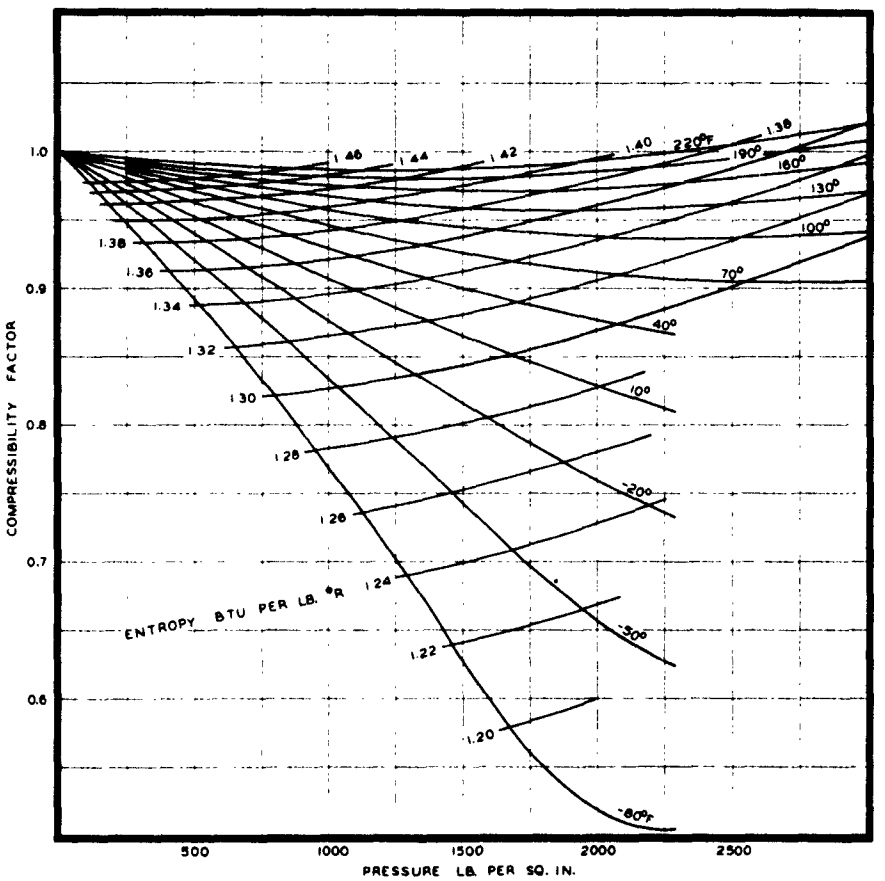

Fig. 5 Pressure-Compressibility Factor Diagram for Nitric Oxide

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II. Analytical Expressions for Thermodynamic Properties

III. Thermodynamic Properties of Nitric Oxide

TABLE I

COEFFICIENTS[a] OF THE BENEDICT EQUATION OF STATE FOR THE VOLUMETRIC BEHAVIOR OF NITRIC OXIDE

Coefficient		Units
A	1630.79	(lb./sq. in.) (cu. ft.)^2 per (lb. mole)^2
B	0.156389	cu. ft. per lb. mole
C	335.287×10^6	(lb./sq. in.) (cu. ft.)^2 ($^\circ$R.)^2 per (lb. mole)^2
a	14188.61	(lb./sq. in.) (cu. ft.)^3 per (lb. mole)^3
b	2.21283	(cu. ft.)^2 per (lb. mole)^2
c	915.645×10^6	(lb./sq. in.) (cu. ft.)^3 ($^\circ$R.)^2 per (lb. mole)^3
α	0.0512202	(cu. ft.)^3 per (lb. mole)^3
γ	0.5000000	(cu. ft.)^2 per (lb. mole)^2

[a] These coefficients yield values of the molal volume.

TABLE II

ANALYTICAL EXPRESSIONS FOR THERMODYNAMIC PROPERTIES

$$P = \frac{RT}{V} + \left(BRT - A - \frac{C}{T^2}\right)\frac{1}{V^2} + \frac{bRT - a}{V^3} + \frac{a\alpha}{V^6} + \frac{c}{T^2 V^3}\left(1 + \frac{\gamma}{V^2}\right)e^{-\frac{\gamma}{V^2}}$$

$$\left(\frac{\partial P}{\partial T}\right)_V = \frac{R}{V} + \frac{1}{V^2}\left(BR + \frac{2C}{T^3}\right) + \frac{1}{V^3}(bR) - \frac{2c}{T^3 V^3}\left(1 + \frac{\gamma}{V^2}\right)e^{-\frac{\gamma}{V^2}}$$

$$S_1 = S_0 + \int_{V_0}^{V^*}\left(\frac{\partial P}{\partial T}\right)_V dV + \int_{T_0}^{T_1}\frac{(C_p^* - b)}{T}dT + \int_{V^*}^{V_1}\left(\frac{\partial P}{\partial T}\right)_V dV$$

$$E_1 = E_0 + T_0\int_{V_0}^{V^*}\left[\left(\frac{\partial P}{\partial T}\right)_V - \frac{P}{T_0}\right]dV + \int_{T_0}^{T_1}(C_p^* - b)\,dT + T_1\int_{V^*}^{V_1}\left[\left(\frac{\partial P}{\partial T}\right)_V - \frac{P}{T_1}\right]dV$$

$$H_1 = E_1 + P_1 V_1$$

$$\ln f = \ln P^* + \frac{P_1 V_1}{bT_1} - 1 - \frac{1}{bT}\int_{V^*}^{V} P\,dV$$

TABLE III

THERMODYNAMIC PROPERTIES OF NITRIC OXIDE

Pressure, Lb. / Sq. In. Absolute	Volume, Cu. Ft./Lb.	Enthalpy, B.t.u./Lb.	Entropy, B.t.u./(Lb.) (°R.)	Fugacity, Lb./Sq. In.
		-80° F.		
10	13.55	93.71	1.6197	9.980
14.696	9.21	93.63	1.5941	14.652
20	6.76	93.53	1.5735	19.919
30	4.50	93.34	1.5463	29.819
40	3.37	93.16	1.5270	39.679
50	2.687	92.98	1.5118	49.499
60	2.235	92.80	1.4994	59.280
80	1.670	92.43	1.4797	78.722
100	1.330	92.07	1.4642	98.007
125	1.059	91.60	1.4486	121.89
150	0.8777	91.14	1.4356	145.52
200	0.6511	90.19	1.4148	192.06
250	0.5151	89.23	1.3981	237.63
300	0.4245	88.26	1.3842	282.22
400	0.3110	86.27	1.3613	368.53
500	0.2427	84.22	1.3425	451.04
600	0.1970	82.09	1.3263	529.77
800	0.1395	77.60	1.2983	676.09
1000	0.1046	72.73	1.2737	807.75
1250	0.0761	65.99	1.2451	952.11
1500	0.0567	58.49	1.2173	1074.8
1750	0.0435	50.78	1.1910	1177.7
2000	0.0353	44.32	1.1692	1265.3
2250	0.0306	39.88	1.1535	1343.9

TABLE III (cont.)

Pressure, Lb. / Sq. In. Absolute	Volume, Cu. Ft./Lb.	Enthalpy, B.t.u./Lb.	Entropy, B.t.u./(Lb.) (°R.)	Fugacity, Lb./Sq. In.
		-50° F.		
10	14.63	100.97	1.6381	9.985
14.696	9.95	100.90	1.6125	14.663
20	7.30	100.82	1.5920	19.939
30	4.86	100.68	1.5650	29.864
40	3.64	100.53	1.5456	39.758
50	2.909	100.381	1.5306	49.621
60	2.420	100.23	1.5183	59.455
80	1.809	99.92	1.4987	79.030
100	1.443	99.62	1.4834	98.486
125	1.150	99.24	1.4679	122.64
150	0.9543	98.86	1.4552	146.60
200	0.7099	98.09	1.4348	193.96
250	0.5633	97.31	1.4186	240.59
300	0.4656	96.52	1.4051	286.47
400	0.3433	94.92	1.3832	376.04
500	0.2698	93.27	1.3655	462.68
600	0.2208	91.58	1.3503	546.48
800	0.1594	88.06	1.3248	705.52
1000	0.1223	84.33	1.3031	853.46
1250	0.0925	79.34	1.2789	1023.2
1500	0.0725	73.95	1.2566	1176.7
1750	0.0584	68.24	1.2353	1314.9
2000	0.0482	62.44	1.2151	1439.3
2250	0.0409	57.00	1.1968	1552.3

TABLE III (cont.)

Pressure, Lb. / Sq. In. Absolute	Volume, Cu. Ft./Lb.	Enthalpy, B.t.u./Lb.	Entropy, B.t.u./(Lb.) (°R.)	Fugacity, Lb./Sq. In.
		-20° F.		
10	15.70	108.19	1.6553	9.989
14.696	10.68	108.13	1.6296	14.671
20	7.84	108.06	1.6091	19.954
30	5.22	107.94	1.5821	29.895
40	3.91	107.81	1.5628	39.814
50	3.13	107.69	1.5479	49.708
60	2.601	107.56	1.5356	59.579
80	1.947	107.31	1.5161	79.251
100	1.554	107.06	1.5010	98.830
125	1.239	106.75	1.4857	123.17
150	1.030	106.43	1.4731	147.37
200	0.7675	105.79	1.4530	195.33
250	0.6102	105.15	1.4371	242.71
300	0.5054	104.50	1.4240	289.52
400	0.3743	103.17	1.4027	381.45
500	0.2956	101.82	1.3857	471.12
600	0.2431	100.44	1.3713	558.57
800	0.1775	97.58	1.3473	726.96
1000	0.1380	94.60	1.3274	886.84
1250	0.1065	90.68	1.3057	1075.2
1500	0.0855	86.55	1.2863	1251.2
1750	0.0706	82.23	1.2683	1415.6
2000	0.0597	77.81	1.2514	1569.5
2250	0.0515	73.40	1.2356	1714.1

TABLE III (cont.)

Pressure, Lb./Sq. In. Absolute	Volume, Cu. Ft./Lb.	Enthalpy, B.t.u./Lb.	Entropy, B.t.u./(Lb.)(°R.)	Fugacity, Lb./Sq. In.
		10° F.		
10	16.78	115.38	1.6709	9.991
14.696	11.41	115.32	1.6455	14.677
20	8.38	115.27	1.6249	19.964
30	5.58	115.16	1.5980	29.918
40	4.18	115.06	1.5788	39.853
50	3.34	114.96	1.5639	49.770
60	2.784	114.85	1.5517	59.669
80	2.084	114.64	1.5323	79.411
100	1.664	114.42	1.5172	99.081
125	1.328	114.16	1.5020	123.56
150	1.104	113.89	1.4895	147.93
200	0.8843	113.35	1.4696	196.32
250	0.6563	112.81	1.4540	244.27
300	0.5443	112.26	1.4411	291. ?
400	0.4043	111.15	1.4203	385.42
500	0.3204	110.01	1.4037	477.33
600	0.2644	108.86	1.3898	567.50
800	0.1945	106.49	1.3670	742.83
1000	0.1526	104.04	1.3482	911.58
1250	0.1191	100.85	1.3282	1113.8
1500	0.0969	97.55	1.3106	1306.7
1750	0.0812	94.14	1.2946	1491.0
2000	0.0697	90.71	1.2799	1667.4
2250	0.0608	87.17	1.2659	1836.8

TABLE III (cont.)

Pressure, Lb. / Sq. In. Absolute	Volume, Cu. Ft./Lb.	Enthalpy, B.t.u./Lb.	Entropy, B.t.u./(Lb.) (°R.)	Fugacity, Lb./Sq. In.
		40° F.		
10	17.85	122.54	1.6857	9.993
14.696	12.14	122.50	1.6604	14.680
20	8.92	122.45	1.6398	19.971
30	5.94	122.36	1.6129	29.934
40	4.45	122.27	1.5937	39.883
50	3.56	122.18	1.5788	49.816
60	2.965	122.09	1.5666	59.735
80	2.220	121.91	1.5473	79.530
100	1.774	121.73	1.5323	99.265
125	1.416	121.50	1.5172	123.85
150	1.178	121.27	1.5048	148.35
200	0.8804	120.82	1.4851	197.07
250	0.7017	120.35	1.4696	245.44
300	0.5826	119.88	1.4569	293.44
400	0.4338	118.93	1.4364	388.41
500	0.3445	117.97	1.4202	482.02
600	0.2850	116.99	1.4067	574.25
800	0.2107	115.00	1.3846	754.83
1000	0.1662	112.94	1.3666	930.32
1250	0.1308	110.29	1.3477	1143.1
1500	0.1073	107.57	1.3313	1348.9
1750	0.0907	104.79	1.3166	1548.3
2000	0.0784	101.98	1.3032	1742.1
2250	0.0690	99.15	1.2907	1930.7

TABLE III (cont.)

Pressure Lb. / Sq. In. Absolute	Volume, Cu. Ft./Lb.	Enthalpy, B.t.u./Lb.	Entropy, B.t.u./(Lb.) (° R.)	Fugacity, Lb./Sq. In.
		70° F.		
10	18.93	129.70	1.6998	9.994
14.696	12.88	129.66	1.6742	14.683
20	9.46	129.62	1.6539	19.977
30	6.30	129.55	1.6268	29.947
40	4.73	129.47	1.6078	39.905
50	3.78	129.39	1.5929	49.852
60	3.15	129.32	1.5807	59.786
80	2.357	129.15	1.5614	79.620
100	1.883	128.98	1.5464	99.408
125	1.504	128.80	1.5314	124.07
150	1.252	128.60	1.5191	148.67
200	0.9361	128.20	1.4995	197.64
250	0.7467	127.80	1.4841	246.33
300	0.6205	127.40	1.4715	294.73
400	0.4626	126.58	1.4513	390.72
500	0.3681	125.75	1.4353	485.60
600	0.3051	124.91	1.4221	579.44
800	0.2264	123.21	1.4005	764.06
1000	0.1793	121.46	1.3832	944.82
1250	0.1418	119.23	1.3651	1165.7
1500	0.1170	116.95	1.3495	1381.5
1750	0.0995	114.64	1.3358	1592.6
2000	0.0864	112.30	1.3233	1799.8
2250	0.0765	109.97	1.3118	2003.5
2500	0.0686	107.66	1.3011	2204.4
2750	0.0623	105.38	1.2911	2403.1
3000	0.0572	103.17	1.2817	2600.0

TABLE III (cont.)

Pressure, Lb. / Sq. In. Absolute	Volume, Cu. Ft./Lb.	Enthalpy, B.t.u./Lb.	Entropy, B.t.u./(Lb.) (°R.)	Fugacity, Lb./Sq. In.
		100° F.		
10	20.01	136.84	1.7127	9.995
14.696	13.61	136.81	1.6873	14.686
20	10.00	136.78	1.6670	19.981
30	6.66	136.72	1.6401	29.958
40	5.00	136.65	1.6209	39.923
50	3.99	136.58	1.6061	49.881
60	3.33	136.51	1.5939	59.828
80	2.492	136.37	1.5747	79.693
100	1.992	136.23	1.5597	99.520
125	1.591	136.05	1.5447	124.25
150	1.325	135.89	1.5324	148.92
200	0.9912	135.53	1.5129	198.09
250	0.7912	135.18	1.4977	247.03
300	0.6578	134.83	1.4852	295.74
400	0.4912	134.13	1.4652	392.51
500	0.3913	133.41	1.4494	488.40
600	0.3247	132.68	1.4363	583.46
800	0.2417	131.21	1.4152	771.25
1000	0.1920	129.72	1.3984	956.02
1250	0.1524	127.81	1.3808	1183.3
1500	0.1263	125.87	1.3659	1406.8
1750	0.1077	123.92	1.3528	1627.2
2000	0.0940	121.96	1.3410	1844.9
2250	0.0834	120.01	1.3302	2060.4
2500	0.0751	118.07	1.3202	2274.4
2750	0.0684	116.17	1.3109	2487.3
3000	0.0629	114.31	1.3021	2699.5

TABLE III (cont.)

Pressure, Lb. / Sq. In. Absolute	Volume, Cu. Ft./Lb.	Enthalpy, B.t.u./Lb.	Entropy, B.t.u./(Lb.)(°R.)	Fugacity, Lb./Sq. In.
		130° F.		
10	21.08	143.99	1.7253	9.996
14.696	14.34	143.96	1.6999	14.688
20	10.54	143.93	1.6794	19.985
30	7.02	143.87	1.6524	29.965
40	5.26	143.81	1.6334	39.937
50	4.21	143.75	1.6185	49.902
60	3.51	143.69	1.6064	59.858
80	2.628	143.57	1.5872	79.748
100	2.101	143.45	1.5723	99.606
125	1.679	143.30	1.5573	124.39
150	1.398	143.15	1.5450	149.12
200	1.046	142.84	1.5256	198.44
250	0.8355	142.53	1.5104	247.57
300	0.6950	142.22	1.4980	296.53
400	0.5195	141.60	1.4781	393.90
500	0.4142	140.98	1.4625	490.60
600	0.3441	140.34	1.4496	586.65
800	0.2566	139.06	1.4289	776.88
1000	0.2043	137.77	1.4123	964.88
1250	0.1627	136.12	1.3953	1197.2
1500	0.1351	134.47	1.3809	1426.9
1750	0.1156	132.80	1.3682	1654.5
2000	0.1011	131.14	1.3569	1880.4
2250	0.0900	129.49	1.3467	2105.4
2500	0.0812	127.85	1.3372	2329.7
2750	0.0741	126.25	1.3284	2553.8
3000	0.0682	124.68	1.3202	2778.3

TABLE III. (cont.)

Pressure, Lb. / Sq. In. Absolute	Volume, Cu. Ft./Lb.	Enthalpy, B.t.u./Lb.	Entropy, B.t.u./(Lb.) (°R.)	Fugacity, Lb./Sq. In.
		160° F.		
10	22.16	151.13	1.7372	9.997
14.696	15.07	151.11	1.7115	14.689
20	11.07	151.08	1.6911	19.987
30	7.38	151.03	1.6641	29.971
40	5.53	150.98	1.6451	39.948
50	4.43	150.92	1.6302	49.918
60	3.69	150.87	1.6181	59.882
80	2.763	150.76	1.5989	79.790
100	2.209	150.65	1.5840	99.674
125	1.766	150.52	1.5691	124.49
150	1.470	150.38	1.5569	149.27
200	1.101	150.11	1.5375	198.72
250	0.8795	149.84	1.5224	248.01
300	0.7318	149.56	1.5100	297.16
400	0.5475	149.02	1.4903	395.02
500	0.4369	148.47	1.4748	492.34
600	0.3632	147.92	1.4620	589.17
800	0.2713	146.80	1.4416	781.37
1000	0.2164	145.67	1.4253	972.01
1250	0.1727	144.24	1.4086	1208.3
1500	0.1437	142.81	1.3945	1442.8
1750	0.1232	141.38	1.3823	1676.2
2000	0.1079	139.96	1.3714	1908.7
2250	0.0962	138.55	1.3615	2141.1
2500	0.0869	137.16	1.3525	2373.6
2750	0.0794	135.80	1.3441	2606.8
3000	0.0733	134.47	1.3362	2841.1

TABLE III (cont.)

Pressure, Lb. / Sq. In. Absolute	Volume, Cu. Ft./Lb.	Enthalpy, B.t.u./Lb.	Entropy, B.t.u./Lb. (°R.)	Fugacity, Lb./Sq. In.
		190° F.		
10	23.23	158.27	1.7483	9.998
14.696	15.80	158.25	1.7225	14.691
20	11.61	158.23	1.7021	19.990
30	7.74	158.18	1.6752	29.976
40	5.80	158.13	1.6562	39.957
50	4.64	158.08	1.6413	49.933
60	3.87	158.03	1.6292	59.904
80	2.898	157.94	1.6100	79.828
100	2.317	157.84	1.5952	99.733
125	1.852	157.72	1.5802	124.58
150	1.543	157.60	1.5680	149.40
200	1.156	157.37	1.5487	198.95
250	0.9236	157.13	1.5337	248.37
300	0.7687	156.88	1.5213	297.67
400	0.5754	156.40	1.5017	395.95
500	0.4595	155.92	1.4863	493.78
600	0.3822	155.42	1.4737	591.23
800	0.2859	154.44	1.4534	785.05
1000	0.2283	153.45	1.4373	977.71
1250	0.1824	152.21	1.4209	1217.2
1500	0.1520	150.97	1.4072	1455.7
1750	0.1305	149.73	1.3952	1693.7
2000	0.1145	148.51	1.3847	1931.5
2250	0.1022	147.30	1.3751	2169.8
2500	0.0925	146.12	1.3664	2408.9
2750	0.0846	144.96	1.3583	2649.4
3000	0.0781	143.82	1.3508	2891.4

TABLE III (cont.)

Pressure, Lb. / Sq. In. Absolute	Volume, Cu. Ft./Lb.	Enthalpy, B.t.u./Lb.	Entropy, B.t.u./(Lb.) (°R.)	Fugacity, Lb./Sq. In.
		220° F.		
10	24.30	165.42	1.7586	9.998
14.696	16.53	165.39	1.7329	14.691
20	12.15	165.37	1.7127	19.991
30	8.10	165.32	1.6857	29.979
40	6.07	165.28	1.6666	39.963
50	4.85	165.24	1.6519	49.942
60	4.05	165.20	1.6397	59.918
80	3.03	165.11	1.6206	79.855
100	2.425	165.03	1.6057	99.776
125	1.939	164.92	1.5908	124.65
150	1.615	164.81	1.5786	149.501
200	1.210	164.60	1.5594	199.12
250	0.9672	164.39	1.5443	248.64
300	0.8053	164.17	1.5320	298.08
400	0.6030	163.74	1.5125	396.67
500	0.4818	163.31	1.4972	494.93
600	0.4010	162.88	1.4846	592.87
800	0.3002	162.01	1.4645	787.96
1000	0.2400	161.13	1.4486	982.32
1250	0.1920	160.05	1.4325	1224.3
1500	0.1602	158.97	1.4189	1466.0
1750	0.1377	157.90	1.4073	1707.7
2000	0.1210	156.84	1.3969	1949.8
2250	0.1080	155.81	1.3877	2192.9
2500	0.0978	154.80	1.3792	2437.3
2750	0.0896	153.80	1.3713	2683.4
3000	0.0828	152.84	1.3641	2931.8