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DEVELOPMENT OF A HIGH-PRECISION VAPOR-PRESSURE
EQUATION AND ITS APPLICATION TO WATER

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INTRODUCTION

The vapor pressure of a liquid is one of its most important and useful thermodynamic properties. It is, therefore, not surprising that the experimental determination of vapor pressure has received the careful attention of many investigators during the past seventy-five years. The results of their efforts have been extremely fruitful so that the literature now contains a vast amount of data on the vapor pressure of many different compounds. Naturally, the precision with which the data have been taken varies, depending upon the objective of any specific investigation. The cruder, less expensive, and less time-consuming observations have given results whose reliability is of the order of a few percent, while the exceedingly tedious, careful, and rather costly studies have yielded results whose reliability is of the order of a few hundredths of one percent.

Paralleling the accumulation of experimental vapor-pressure data has been the development of various algebraic relations to correlate the data. The majority of all correlations have as their starting point the well-known Clapeyron equation,

$$dP/dT = \Delta H/T\Delta V \quad (1)$$

where P is pressure, T is temperature, ΔH is the change of enthalpy in passing from the liquid to the gas phase, and ΔV is the change of volume from the liquid to the gas. By assuming that the volume of the liquid is negligible, that the gas behaves ideally, and that the enthalpy change does not vary with temperature or pressure, integration of Eq. (1) gives the simplest form of vapor-pressure relation,

$$\ln P = A + B/T \quad (2)$$

At low pressures, where the assumptions are quite good, Eq. (2) does an excellent job of representing the data. One of the really surprising things about this equation, however, is that it does a fair job of representing the data all the way to the critical point where the liquid no longer exists. This fact was noted by early investigators who plotted $\ln P$ versus $1/T$, as suggested by Eq. (2). They found that within the limit of precision of their observations plots of $\ln P$ versus $1/T$

yielded practically straight lines from the triple point to the critical point. This can hardly be said to be expected because all three of the assumptions leading to Eq. (2) become extremely bad as the critical temperature is approached. For some reason, though, the assumptions evidently fail in a compensating manner, so that the linearity of $\ln P$ and $1/T$ is approximately preserved all the way to the critical point.

It was not too long before more refined data became available, and these indicated that the $\ln P - 1/T$ plots curve down very slightly at the low temperatures or high values of $1/T$. Accordingly, modifications of Eq. (2) were suggested to account for this long sweeping downward curvature at low temperatures. The modifications seemed so successful that it appeared the problem of representing vapor-pressure data had been solved. Unfortunately, this did not prove to be the case, for the experimental investigators went back to their laboratories and refined their measurements even further. When again their results were plotted on the $\ln P - 1/T$ coordinates, it was found that not only was there a slight downward curvature at the low temperatures, but there was a slight upward curvature at the highest temperatures. Only the most precise data reveal this minute "S"-shaped behavior or inflection in the curve, but it is real and has been called attention to more or less independently by Thodos (12), Waring (13), Plank and Riedel (7), and Martin and Hou (3).

One would guess that it should not have been too difficult to modify Eq. (2) further to account for the slight "S" - ing of the most precise vapor-pressure data, but this did not prove to be the case. Although many persons studied the problem and many suggestions were made as to the proper form an equation should have in order to correct for the small deviations from a straight line, none of them has been successful, as far as can be determined from the published literature which has reached the authors' attention. The only practical solution to the problem so far has been to utilize two or more equations, each representing the data over certain limited ranges of temperature. In the overlapping ranges of temperature the equations are adjusted so that they predict the same vapor pressures, and occasionally even the same derivatives of pressure with respect to temperature. Although this has proven to be a workable arrangement, it is awkward and not completely satisfying. It would be much more desirable to develop a single equation which can represent the data within its experimental precision over the entire temperature range. In the course of developing equations to calculate thermodynamic properties

on an automatic computer, it was decided worthwhile to spend some time studying vapor-pressure behavior with the objective of trying to develop such a single equation,

At the start of the study there were available a number of summaries of the more important vapor-pressure equations which had been presented in the literature. One of these by Waring (13) is considered exceptionally good because it not only presents a few of the better equations, but it also points out some of the necessary characteristics which must be possessed by any universal wide-range vapor-pressure equation. Additionally, the senior author of the present paper had had considerable experience applying several forms of equations to a number of different compounds. One of the forms is the rather well-known equation,

$$\ln P = A + B/T + C \ln T + DT \quad (3)$$

It was found that no other equation containing only four arbitrary constants would do as good an overall job of representing the data as this one. It appeared there was something fundamental in character in this equation besides the fact that its first two terms are the same as Eq. (2). That this is the case will be shown shortly in comparing with the new equation which is developed in this paper. Nevertheless, as good as is Eq. (3), it always had to be applied over limited ranges of temperature. The usual situation found one set of constants serving to fit the upward curving part of the "S" at higher temperatures and another set of constants being used for the downward curving portion at lower temperatures. A number of different kinds of terms were added to Eq. (3) to try to get a single equation which would cover the complete temperature range for a given compound. These were usually terms which increased rapidly near the critical temperature in order to account for the upward curvature. Also the last term of Eq. (3) was modified by raising the power on T up to as high as 25. None of these techniques would accomplish the desired job, however, so it was decided to start over with a new analysis of the problem.

DEVELOPMENT OF THE NEW EQUATION

The best approach appeared to be to select a single compound for which there were available data of the highest known experimental precision and of the widest possible range in pressure. If an equation could be developed to fit this compound, such an equation would more than likely be applicable to any compound. The logical selection for this purpose was ordinary water. The literature showed that more time and effort had been spent studying the vapor pressure (also the latent heat and volume changes) of water than of any other compound. There was available a compilation of all of the experimental data as presented by Osborne, Stimson, and Ginnings (6) which was complete and contained all of the latest information. Consequently, the following analysis was based on their numbers.

Because of the rather complicated function that vapor pressure is of temperature, it was decided to differentiate the data several times until a simple function would result, with the hope that latter function would be amenable to algebraic treatment. The first graph constructed from the Osborne, Stimson, and Ginnings tables was the conventional $\ln P$ versus $1/T$, as shown in Fig. (1). The "S" effect has been slightly exaggerated on this plot to emphasize its existence, as it is not readily obvious on a graph of this small size. On the original large-scale plot there was not the slightest question about this characteristic of the curve.

The second step was to differentiate the curve of Fig. (1) to obtain the derivative, $d(\ln P)/d(1/T)$, as a function of T . Since direct graphical differentiation is dependent upon the operator and the particular technique employed, numerical differentiation of the tabulated data was chosen as a better alternative. Also the tabulations of Osborne et al were at convenient 5° intervals of temperature all the way from the triple point to the critical point, which made numerical differentiation simple. The results of this calculation are given in Fig. (2), where it is noted that the ordinate is the variable M defined by the equation $M = -d(\ln P)/d(1/T)$, which is the negative of the derivative of Fig. (1). Only the smooth curve of the results is shown, though the original plot showed the derivatives as lines rather than points, for the 5° interval over which they were obtained.

A third graph was constructed by numerically differentiating the data lead-

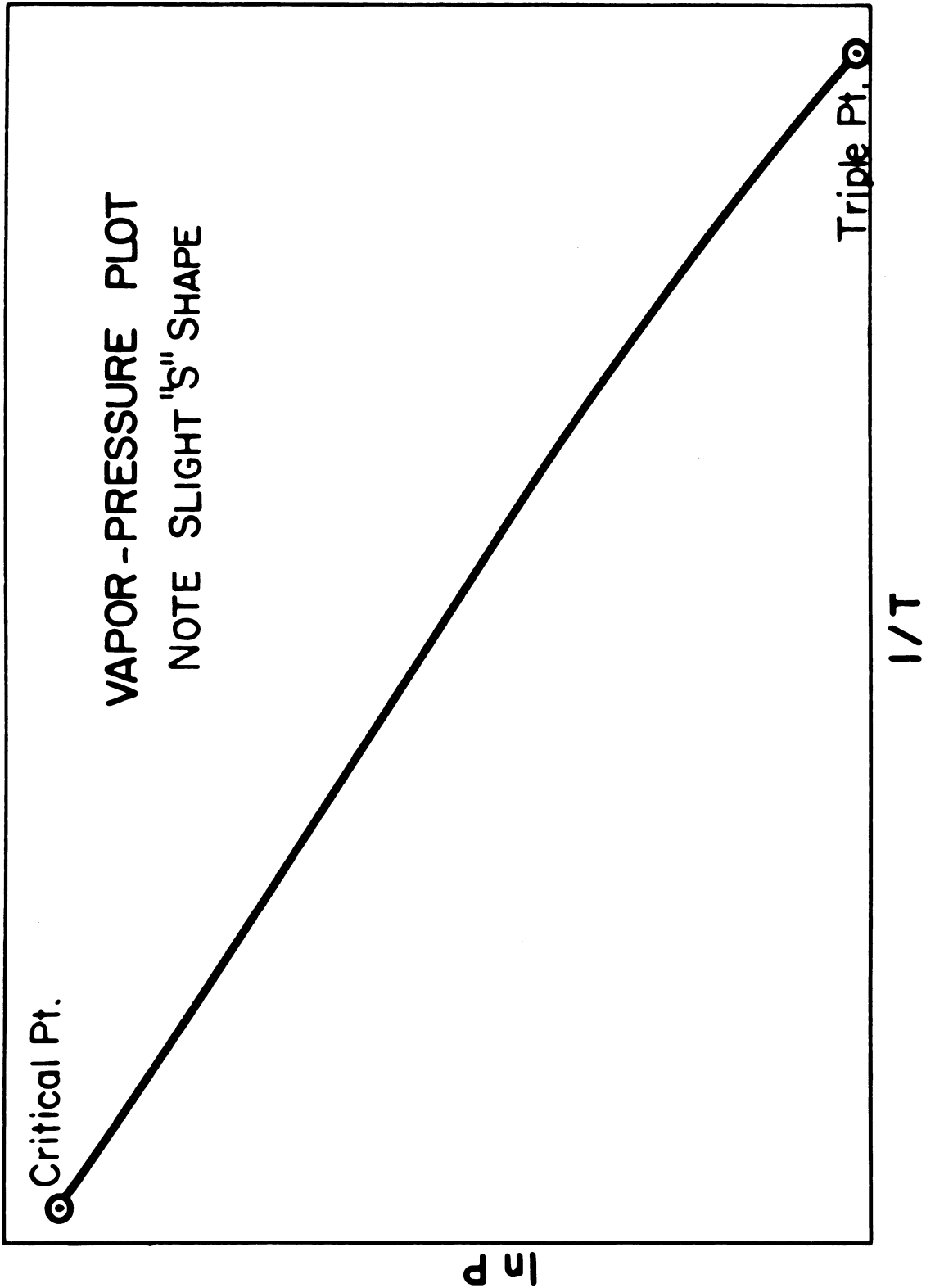


Figure 1.

ing to Fig. (2). The result of this operation is shown in Fig. (3) where the derivative, dM/dT , is plotted versus T . Again only the smooth curve is shown, though the numerical differentiation procedure gave some scatter to the actual line intervals plotted. A fourth and last graph was obtained by performing one more differentiation. This was also done by the numerical procedure and the smoothed result is shown in Fig. (4). Here the scatter of the plotted data was so great that it was apparent nothing more would be gained by further differentiation. If the shape of this last curve of d^2M/dT^2 versus T could be verified, it was felt that a solution to the problem of developing a vapor-pressure equation might easily be obtained because the curve is seen to be a practically straight line up to very high temperature where it undergoes an upward sweep. The algebraic description of such a curve would be fairly simple since it would be merely a linear function over the greater part of the temperature range and simply contain a term which would add appreciably only at high temperature.

Because of the scatter of the second derivatives on Fig. (4), a check of the shape of the curve was undertaken by means of the Clapeyron relation. If Eq. 1 is written in the form,

$$dP = (\Delta H/\Delta V)dT/T \quad (4)$$

it is seen that the simple operations of dividing both sides by P and multiplying the right-hand side by T/T gives

$$dP/P = (T\Delta H/P\Delta V)(dT/T^2)$$

or

$$-d(\ln P)/d(1/T) = T\Delta H/P\Delta V = M \quad (5)$$

In this form the slope of the curve on $\ln P - 1/T$ coordinates is given by undifferentiated data involving the latent heat and volume changes as well as the pressure and temperature. Since these data were tabulated by Osborne et al, the quantity M was calculated as $T\Delta H/P\Delta V$ and plotted versus T . The result was identical with Fig. (2), but the variation in the plotted points was much less because no differentiation of primary data was required. Following the same procedure as before, the $T\Delta H/P\Delta V$ data were numerically differentiated with respect to temperature and the results plotted as dM/dT versus T on Fig. (3). The curve agreed well with that obtained from only the vapor-pressure data, but again the scatter of points was reduced. Of course, the agreement between the several curves obtained from the two kinds of data was expected because of the statement given in the Osborne et al paper that

$$M = -\frac{d \ln P}{d(1/T)} = \frac{T \Delta H}{P \Delta V}$$

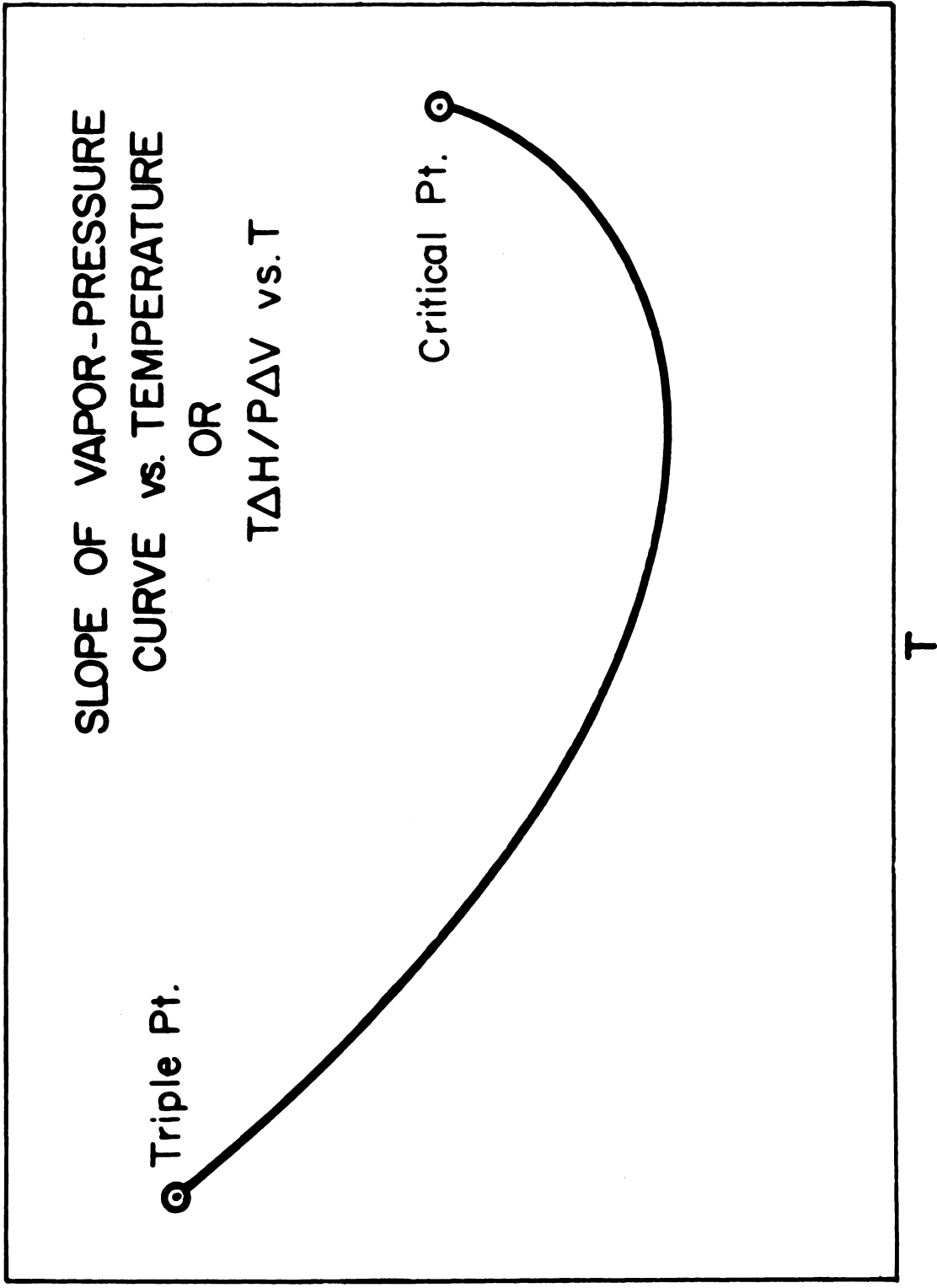


Figure 2.

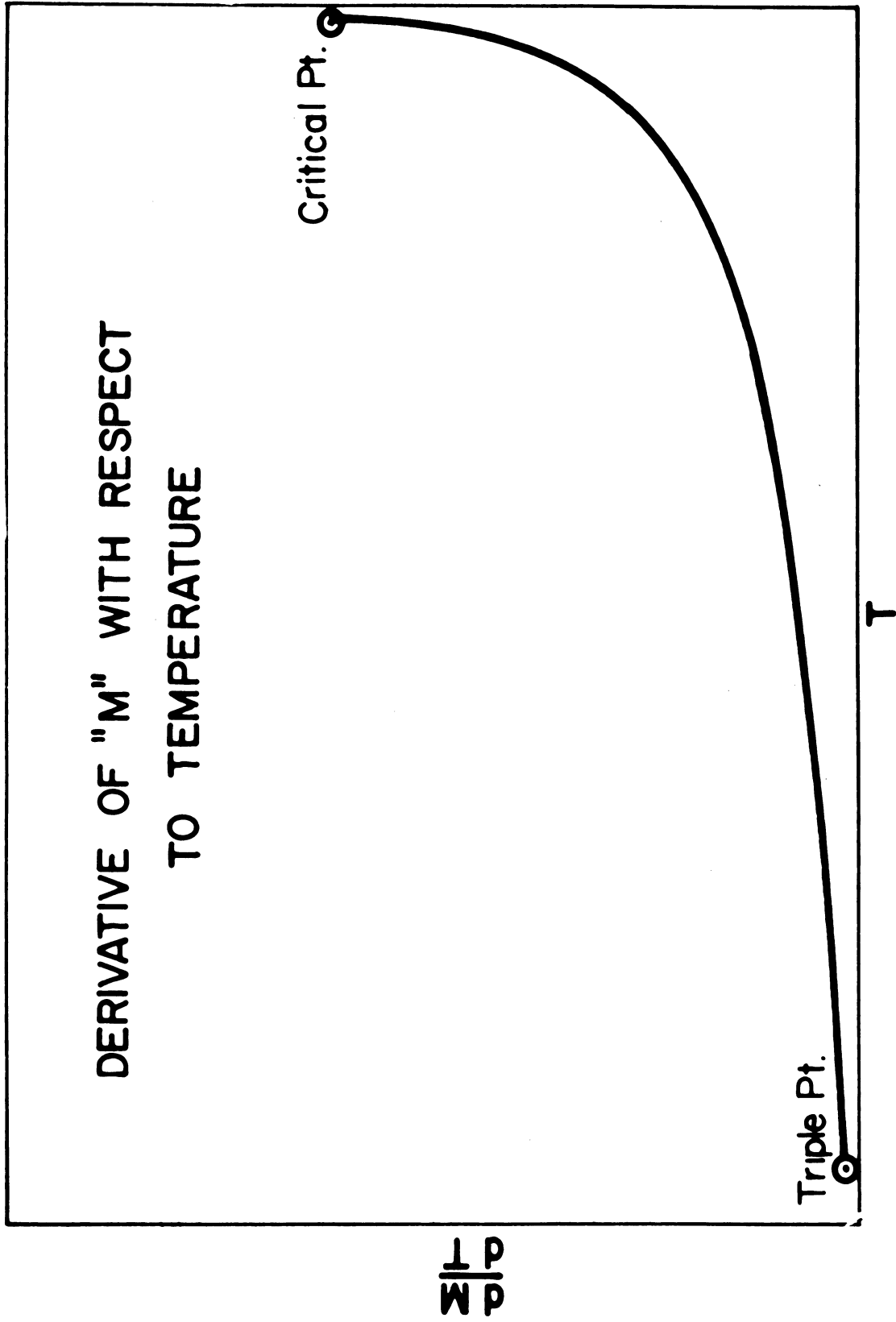


Figure 3.

the tabulations were internally consistent with the Clapeyron equation.

A second numerical differentiation of the $T\Delta H/P\Delta V$ data was made to give d^2M/dT^2 which was plotted on Fig. (4). Because of the smaller scatter of the data, the curve was much better defined than that given by the thrice-differentiated pressure-temperature data. There was no doubt now but what the curve was a straight line (and almost horizontal) over most of its length, curving upward only at the highest temperatures.

To represent algebraically the curve of Fig. (4), it was apparent that the function would probably contain two parts: first, a linear function, and second, a term which would be appreciable only at high temperature and would damp out at low temperatures. Several different forms of the second term were tried, such as simple powers of T , exponentials, and logarithms of T . These were added to either a constant or a constant plus another constant times temperature. The final selection of the whole function which seemed to fit the data the best was

$$d^2M/dT^2 = a + c/(b - T)^n \quad (6)$$

Various values of n were assumed until the desired shape of the curve was obtained. These included $1/2$, 1 , $3/2$, 2 , and 3 . The value of 2 was selected as being slightly better than 3 , so that the completely determined function became

$$d^2M/dT^2 = a + c/(b - T)^2 \quad (7)$$

Now by integration the desired vapor-pressure equation may be obtained in a straight-forward fashion. Thus,

$$dM/dT = aT + c/(b - T) + I_1 \quad (8)$$

and

$$M = aT^2/2 - c \ln(b - T) + I_1T + I_2 \quad (9)$$

where I_1 and I_2 are constants of integration. From the definition of M , rearrangement and final integration gives

$$M = -d(\ln P)/d(1/T) = T^2d(\ln P)/dT$$

or

$$d(\ln P) = (M/T^2)dT$$

or

$$d(\ln P) = [a/2 - (c/T^2)\ln(b - T) + I_1/T + I_2/T^2] dT$$

or

$$\ln P = aT/2 - (c/b)\ln T - [c(b - T)/bT] \ln(b - T) + I_1\ln T - I_2/T + I_3 \quad (10)$$

Combining terms and defining new constants results in the final form of the vapor-pressure equation,

$$\ln P = A + B/T + C \ln T + DT + [E(b - T)/bT] \ln(b - T) \quad (11)$$

SECOND DERIVATIVE OF "M" WITH
RESPECT TO TEMPERATURE

$$\frac{d^2M}{dT^2}$$

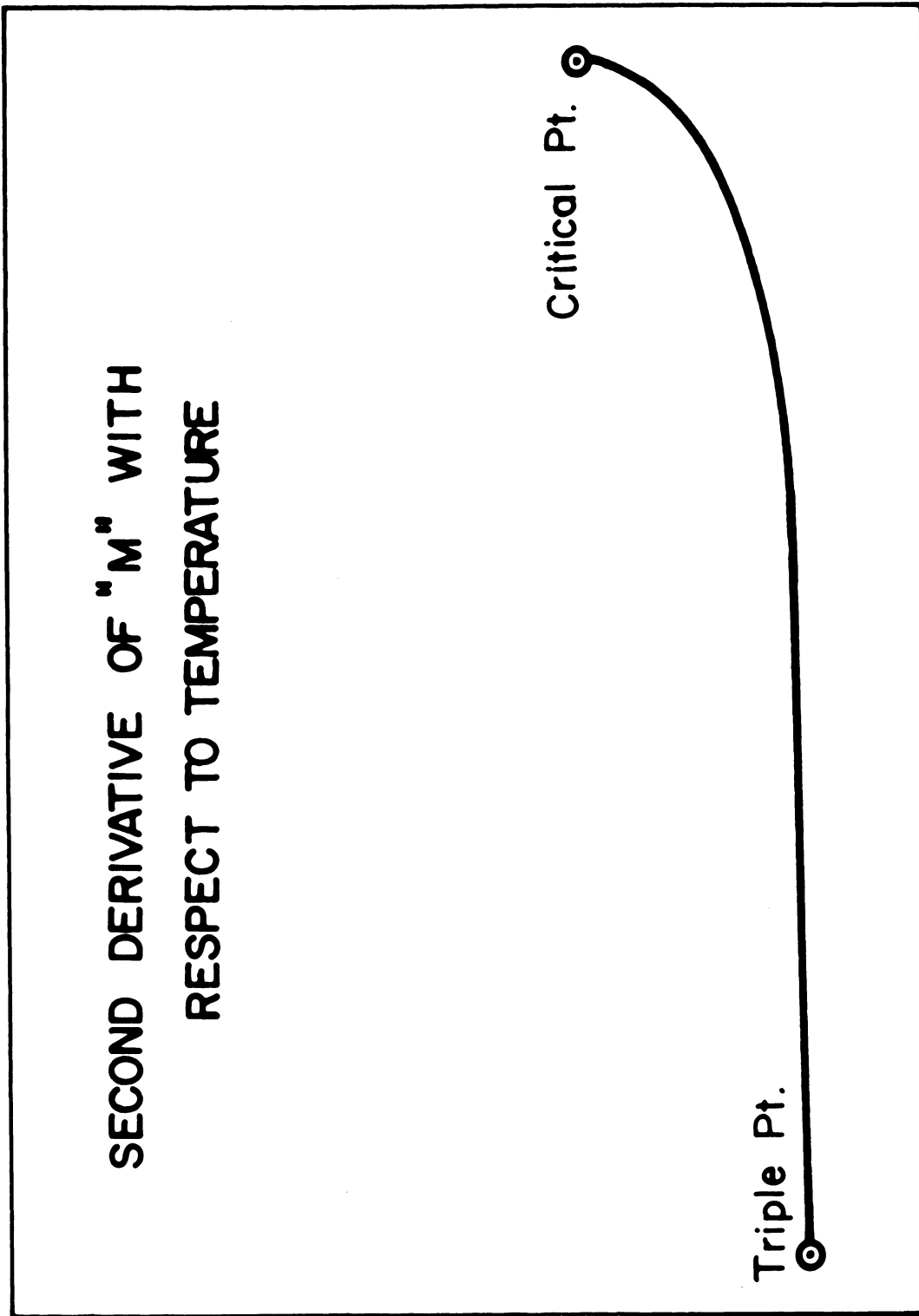


Figure 4.

It is seen immediately that this equation has four terms exactly the same as Eq. (3). These first four terms arise from the horizontal portion of the curve of Fig. (4), which is represented by a. The upward curving portion of this curve is represented by $c/(b - T)^2$, and this leads to the additional fifth term of Eq. (11).

The constants of Eq. (11) for water were obtained by first determining b so that the upward sweep on Fig. (4) would be properly represented. The other constants, A, B, C, D, and E, were determined by passing the equation through five representative vapor-pressure data points. A least squares procedure was also tried for these five constants, but it was not as successful as that involving the selection of five points. The constants were also checked against the various derivative curves. The equation with the constants evaluated is

$$\ln P = 78.57024489 - \frac{8851.132005}{T} - 9.965956346 \ln T + 0.007757635855 T + \frac{200.2299050(655.83 - T) \ln (655.83 - T)}{655.83 T} \quad (12)$$

where P is in Kg/cm² and T is in °K which is taken to be (°C + 273.16). The calculations of these constants and of the vapor pressures from the equation were carried out on an IBM-650 machine or a desk calculator using ten significant figures. This is why the constants are given to ten figures. It is clear that these could be rounded off somewhat to reflect the precision of the data.

COMPARISON OF THE EQUATION WITH EXPERIMENTAL DATA

Initially the new equation was compared with the tabulated data of Osborne et al (6), and a smooth deviation curve was obtained. This at first appeared to mean that Eq. (12) differed from the truth in some systematic manner; however, it was noted that Osborne did not tabulate actual experimental results. The values given in the tables were the result of equations which had been formulated to represent the data over various ranges of temperature. Such a comparison, therefore, was not a real test of the precision of the new equation, for it simply compared one equation against another. A true test required making the comparison with the original results from the laboratory. Consequently, a search was made of all of the published vapor-pressure measurements of water taken since 1900, and those which were considered the most reliable were selected for comparison. It was a bit surprising to find that the accord between some investigations was not quite as good as one would be led to believe from the smooth tabulations. The accompanying table and Fig. (5) present the comparisons between the equation and the experimental data. Not all of the original data of each investigator is reported here, but the choice of the particular points is believed representative and without prejudice.

In studying the comparisons it is to be noted that the percent deviations are nowhere very large, since in the worst case there is a difference of only 0.41 percent. This occurs with the data of Holborn and Henning (2). It is clear, however, that at certain temperatures their data are in considerable disagreement with those of Scheel and Heuse (9), Osborne, Stimson, Fiock, and Ginnings (5), Egerton and Callendar (1) and Smith, Keyes, and Gerry (10), so that the equation appears to be closer to the truth than their data at these temperatures. The next least satisfactory comparisons are those with Scheel and Heuse (9) where the greatest deviations are 0.16 and 0.12 percent. It is interesting here that in the neighborhood of 0°C Scheel and Heuse have a discrepancy of 0.16 percent in their own results. In their most refined experiment at 0°C, they obtained a vapor pressure of 4.576 mm Hg, as a result of six independent measurements. This deviates from the equation by only -0.044 percent. Scheel and Heuse (8) in an earlier experiment, and Thiessen and Scheel (11) obtained 4.579 for this pressure, which differs from the equation by +0.022 percent. These extremely small positive and negative deviations indicate the equation is doing a very satisfactory job right at 0°C. Since the true values of vapor pressure will not likely differ greatly from the equation over the next 16°,

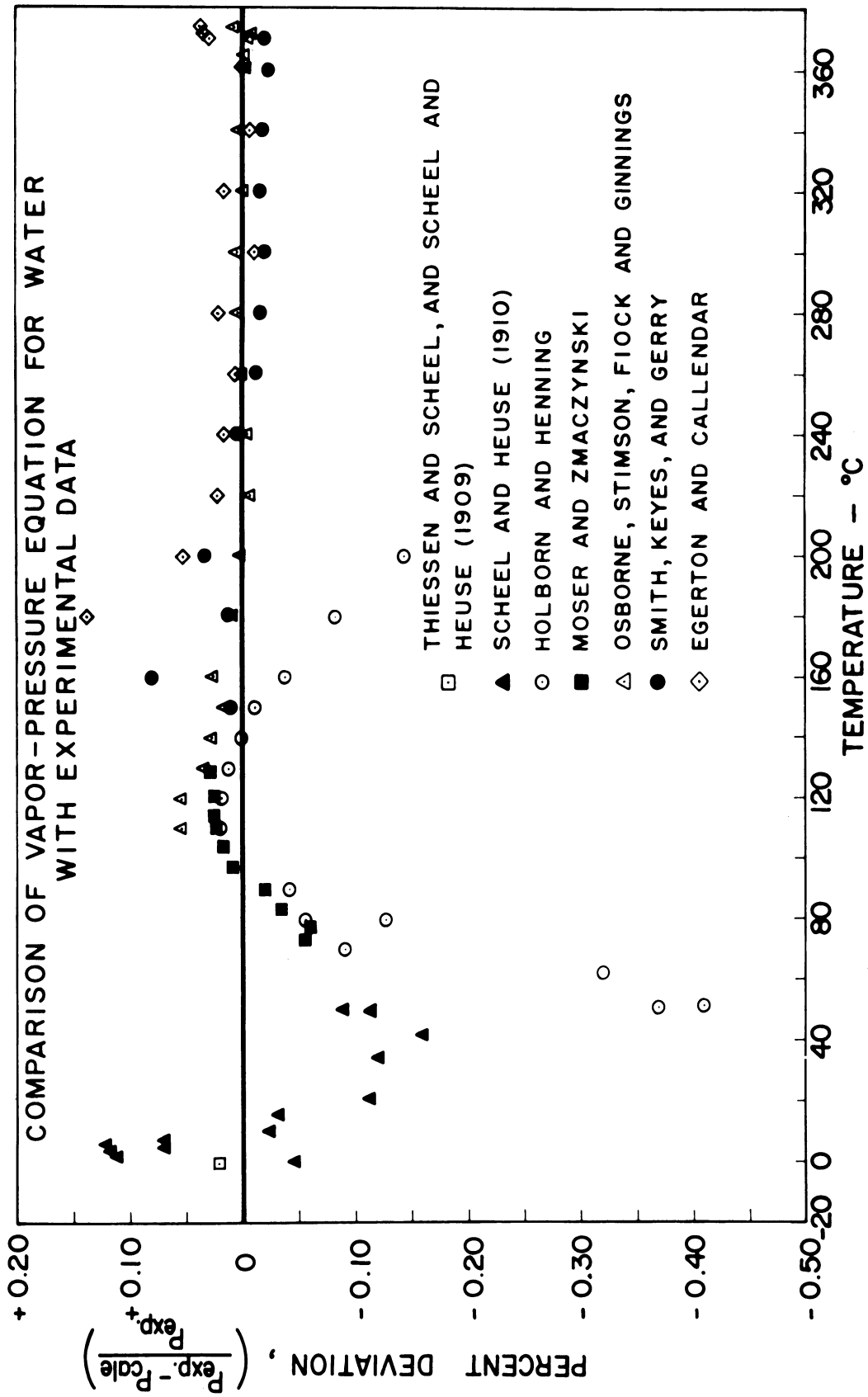


Figure 5.

it appears that the next 7 points of Scheel and Heuse from 0 to 16°C simply average around the prediction of the equation and can hardly indicate a trend from the equation. Between 20° and 70°C the preponderance of the experimental data indicates a negative deviation and one may conclude the equation may be as much as 0.1 percent off at the worst point. Despite the inconsistencies of a few tenths of a percent between Scheel and Heuse (9), Holborn and Henning (2), and Moser and Zmaczynski (4), the fact that the deviations are all in one direction would indicate the equation probably is predicting just a little bit high. However, because of the differences between experimental investigators, it would be advantageous to have a new independent investigation made of the vapor pressure between 20° and about 70°C. Until such an investigation is made, one cannot really ascertain the truth in this region. When this problem was first encountered, it was thought that the volume and latent-heat data could be used to check the vapor-pressure through the Clapeyron equation. It was found, though, that there were no good volume data available for this purpose. In all the existent tabulations the volumes were calculated by using the latent-heat and vapor-pressure data in the Clapeyron equation. If accurate experimental volume data ever become available, the vapor pressures in this region can be determined.

In connection with the problem of the low-pressure data, it is interesting to note that Osborne, Stimson, and Ginnings (6) in their tables selected the vapor pressure at 0°C to be 4.581 mm Hg, which is 0.1 percent higher than the best measurements of Scheel and Heuse (9). Also, Smith, Keyes, and Gerry developed a vapor-pressure equation to fit the data over the limited range of 10° to 150°C. At 0°C their equation predicts the pressure to be 4.5893 mm Hg which is 0.29 percent above the average of the six measurements of Scheel and Heuse (9). They feel that 4.579, as obtained by Thiessen and Scheel (11) and the earlier investigation of Scheel and Heuse (8) is a better value, but they state "it must correspond either to sub-cooled liquid water or ice," because the normal triple point of water is known to be 0.01°C. They conclude with the statement, "We believe it (the 4.579) to be probably the vapor pressure of sub-cooled water at zero degrees."

One can only conclude that in the low temperature range (i. e., below 70°C) one cannot tell with certainty just what the vapor pressure is within much better than 0.05 to 0.1 percent.

In the other region from 70 to 374.15°C the equation fits the data within 0.05 percent or better, with no particular obvious trends. In fact the equation gives an

excellent average of the results of Holborn and Henning (2), Moser and Zmaczynski (4), Osborne, Stimson, Fiock, and Ginnings (5), Smith, Keyes, and Gerry (10), and Egerton and Callendar (1). By a slight adjustment of the equation constants, it was found that the deviations from Scheel and Heuse between 20 and 70°C could be reduced by a factor of a half, but at higher temperatures the data of the other investigators would not be averaged quite so well. However, the maximum deviation at higher temperatures from 80 to 374.11 was reduced to less than 0.1 percent, which is better than the equation presented, but the average deviation was increased slightly.

Upon examination of all the data from the triple point to the critical, it appears that the new equation does a remarkable job of fitting the data almost within the experimental precision of the measurements of the various investigators, thus offering substantiation for its validity.

There does not seem to be available any vapor-pressure data for other compounds of sufficient accuracy to test the equation down to a few hundredths of a percent. Also what would be more helpful would be to have latent heat and volume data as well as vapor-pressure data. This would permit obtaining more precise values of d^2M/dT^2 . Since the development of the equation, the authors have applied it to other compounds, both polar and non-polar, and it yields scattered deviation curves which indicate it fits the data within the experimental precision. Interestingly enough, it has been found in these other applications that the constant b may be taken as about 8°C above the critical temperature just as in the case of water. It is expected that the application to other compounds will be published in the near future.

One other point is to be mentioned concerning the selection of the algebraic form of Eq. (6). The first term was taken to be a constant even though the graph of d^2M/dT^2 showed a definite positive slope. The reason for this selection was that the slope is very small and the second term, $c/(b - T)^n$, makes a contribution equivalent to a term such as mT which would account for the slope. Some attention, however, was given to making the first term, $a + mT$. It was then found that the exponent n might better be 3 than 2. This new combination of $a + mT + c/(b - T)^3$ was integrated three times to give an equation of the form,

$$\ln P = A + B/T + C \ln T + DT + ET^2 + F \ln(b - T) \quad (13)$$

In some ways this is a simpler expression than Eq. (11), since the last term does not have the coefficient of the logarithm occurring as a temperature function. Preliminary tests with this equation indicated it could do a very satisfactory job of representing the data. Unfortunately, though, time did not permit a complete checking

of this, so that the equation can only be offered here as a good possibility. It is hoped that a thorough comparison of Eq. (11) and (13) can be made during the coming year.

CONCLUSIONS

1. A differential analysis of the precise vapor-pressure, latent heat, and volume data for water shows rather conclusively that d^2M/dT^2 is a straight line with a very small positive slope over a wide temperature range, with an upward sweep as the critical temperature is approached.

2. The representation of the d^2M/dT^2 curve with the expression $a + c/(b - T)^n$ is excellent for $n = 2$. It also appears that the curve may be well represented by $a + mT + c/(b - T)^3$, though this requires further checking.

3. From the algebraic expression for d^2M/dT^2 and the fact that $M = -d(\ln P)/d(1/T)$, three successive integrations give an equation for vapor pressure as a function of temperature.

4. When applied to the experimental data of water, covering a 36,000-fold range in vapor pressure, the new Equation (12) differs only a few hundredths of a percent from the most reliable data and appears to be within about 0.1 percent of data whose precision is only of that order of magnitude. Over most of the temperature range the equation averages the results of several investigators.

5. In the case of the specific application to water, the deviations between different investigators indicate that the low-temperature range might well be the subject of further experimental study. From 70°C to the critical point, 374.15°C, the experimental data are in excellent accord. There is, however, appreciable variation between the various workers in the range from 0 to 70°C.

6. Applications to other compounds, polar and non-polar, indicate the new equation fits their vapor-pressure data equally well. Since the equation is capable of fitting data to within a few hundredths of a percent, it is clear that only the most precise data can be used to test the true characteristics of the equation. In these other applications the constant b is about 8°C above the critical temperature, as it is for water.

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TABLE I
COMPARISON OF VAPOR-PRESSURE EQUATION FOR
WATER WITH EXPERIMENTAL DATA

Equation: $\ln P = 78.57024489 \frac{8851.132005}{T} - 9.965956346 \ln T$
 $+ 0.007757635855 T + \frac{200.229905(655.83 - T) \ln(655.83 - T)}{655.83 T}$ where $P = \text{Kg/cm}^2$
and $T = ^\circ\text{K} =$
 $^\circ\text{C} + 273.16$
(1 atm = 1.033228 Kg/cm² = 760 mm Hg = 29.9212 in Hg =
14.6960 psia = 1.013250 bar)

Temperature °C	Pressure Kg/cm ²		Percent Dev (P _{exp} - P _{calc})/P _{exp}	Investigator
	Experimental	Calculated		
0.000	0.0062252	0.0062238	+0.022	T. & S (11) and S. & H. (1909)(8)
0.000	0.0062211	0.0062238	-0.044	S & H (1910)(9)
1.520	0.0069553	0.0069474	+0.112	"
3.766	0.0081625	0.0081530	+0.117	"
4.574	0.0086356	0.0086298	+0.067	"
5.612	0.0092896	0.0092784	+0.119	"
6.988	0.0102113	0.0102044	+0.067	"
9.578	0.0121676	0.0121705	-0.024	"
15.479	0.0179347	0.0179400	-0.028	"
21.000	0.0253522	0.0253805	-0.112	"
34.478	0.055720	0.055786	-0.120	"
41.710	0.082339	0.082471	-0.161	"
49.293	0.121480	0.121616	-0.111	"
50.026	0.126036	0.126151	-0.091	"
50.692	0.129874	0.130354	-0.369	H. & H. (2)
51.357	0.134143	0.134692	-0.410	"
62.043	0.222647	0.223361	-0.321	"
69.897	0.316304	0.316593	-0.091	"
73.486	0.368865	0.369073	-0.056	M & Z (4)
77.604	0.437901	0.438160	-0.059	"
79.574	0.474605	0.474869	-0.056	H. & H. (2)
79.869	0.479975	0.480582	-0.127	"
83.656	0.55857	0.55876	-0.034	M. & Z. (4)
89.872	0.71140	0.71153	-0.019	"
89.977	0.71408	0.71437	-0.041	H. & H. (2)
97.815	0.95523	0.95514	+0.009	M. & Z (4)
104.123	1.19485	1.19465	+0.017	"
110.000	1.46129	1.46050	+0.054	O., S., F. & G. (5)
110.000	1.46079	1.46050	+0.020	H. & H. (2)
110.347	1.47792	1.47758	+0.023	M. & Z. (4)
114.598	1.70133	1.70090	+0.025	"
120.000	2.02492	2.02381	+0.055	O., S., F., & G. (5)
120.000	2.02417	2.02381	+0.018	H. & H. (2)
120.374	2.04839	2.04793	+0.022	M. & Z. (4)
128.641	2.64409	2.64330	+0.030	"

TABLE I (cont'd)

Temperature °C	Pressure, Kg/cm ²		Percent Dev. (P _{exp} - P _{calc})/P _{exp}	Investigator
	Experimental	Calculated		
130.000	2.75438	2.75348	+0.034	O., S., F. & G. (5)
130.000	2.75382	2.75348	+0.013	H.&H. (2)
140.000	3.68459	3.68359	+0.027	O., S., F. & G. (5)
140.000	3.68359	3.68359	0.000	H.&H. (2)
150.000	4.85297	4.85224	+0.015	O., S., F., & G. (5)
150.000	4.85168	4.85224	-0.011	H.&H. (2)
150.000	4.85276	4.85224	+0.011	S., K. & G. (10)
160.000	6.3025	6.3009	+0.025	O., S., F. & G (5)
160.000	6.2986	6.3009	-0.037	H.&H. (2)
160.000	6.3060	6.3009	+0.081	S., K., & G. (10)
180.000	10.2246	10.2237	+0.009	O., S., F. & G (5)
180.000	10.2154	10.2237	-0.082	H. & H. (2)
180.000	10.2247	10.2237	+0.010	S., K. & G. (10)
180.000	10.2378	10.2237	+0.138	E. & C. (1)
200.000	15.8572	15.8568	+0.002	O., S., F. & G. (5)
200.000	15.8342	15.8568	-0.142	H.&H. (2)
200.000	15.8621	15.8568	+0.033	S., K. & G. (10)
200.000	15.8652	15.8568	+0.053	E. & C. (1)
220.000	23.6572	23.6590	-0.007	O., S., F. & G. (5)
220.000	23.6578	23.6590	-0.005	S., K. & G (10)
220.000	23.6640	23.6590	+0.021	E. & C. (1)
240.000	34.1395	34.1411	-0.005	O., S., F. & G. (5)
240.000	34.1420	34.1411	+0.003	S., K. & G. (10)
240.000	34.1461	34.1411	+0.015	E. & C. (1)
260.000	47.8680	47.8668	+0.003	O., S., F. & G. (5)
260.000	47.8612	47.8668	-0.012	S., K. & G. (10)
260.000	47.8643	47.8668	-0.005	E. & C. (1)
280.000	65.461	65.458	+0.004	O., S., F. & G. (5)
280.000	65.448	65.458	-0.016	S., K. & G. (10)
280.000	65.471	65.458	+0.020	E. & C. (1)
300.000	87.615	87.611	+0.004	O., S., F. & G. (5)
300.000	87.593	87.611	-0.020	S., K. & G. (10)
300.000	87.599	87.611	-0.014	E. & C. (1)
320.000	115.120	115.121	-0.001	O., S., F. & G. (5)
320.000	115.104	115.121	-0.015	S., K. & G. (10)
320.000	115.139	115.121	+0.016	E. & C. (1)
340.000	148.957	148.956	+0.001	O., S., F. & G. (5)
340.000	148.929	148.956	-0.018	S., K. & G. (10)
340.000	148.942	148.956	-0.009	E. & C. (1)
360.000	190.421	190.426	-0.003	O., S., F. & G. (5)
360.000	190.383	190.426	-0.023	S., K. & G. (10)
360.000	190.423	190.426	-0.002	E. & C. (1)
364.000	199.804	199.809	-0.003	O., S., F. & G. (5)
370.000	214.675	214.687	-0.006	O., S., F. & G. (5)
370.000	214.640	214.687	-0.022	S., K. & G. (10)
370.000	214.745	214.687	+0.028	E. & C. (1)

TABLE I (cont'd)

Temperature °C	Pressure, Kg/cm ²		Percent Dev. (P _{exp} -P _{calc})/P _{exp}	Investigator
	Experimental	Calculated		
372.000	219.866	219.883	-0.008	O., S., F. & G (5)
372.000	219.957	219.883	+0.034	E. & C. (1)
374.000	225.228	225.212	+0.007	O., S., F. & G (5)
374.000	275.293	225.212	+0.036	E. & C. (1)

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