NISTIR 6643

The Vapor Pressure of Mercury

Marcia L. Huber
Arno Laesecke
Daniel G. Friend

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

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Marcia L. Huber
Arno Laesecke
Daniel G. Friend
Physical and Chemical Properties Division
Chemical Science and Technology Laboratory
National Institute of Standards and Technology
Boulder, CO 80305-3328

April 2006



U.S. DEPARTMENT OF COMMERCE
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TECHNOLOGY ADMINISTRATION
Robert Cresanti, Under Secretary of Commerce for Technology
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
William Jeffrey, Director

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Marcia L. Huber, Arno Laesecke, and Daniel G. Friend
National Institute of Standards and Technology∗
Boulder, CO 80303-3328

In this report, we review the available measurements of the vapor pressure of mercury and develop a new correlation that is valid from the triple point to the critical point. The equation is a Wagner-type form, where the terms of the equation are selected by use of a simulated annealing optimization algorithm. In order to improve the reliability of the equation at low temperatures, heat capacity data were used in addition to vapor pressure data. We present comparisons with available experimental data and existing correlations. In the region of interest for this project, over the temperature range 0 °C to 60 °C, the estimated uncertainty (estimated as a combined expanded uncertainty with coverage factor of 2, 2σ) of the correlation is 1 %.

Keywords: correlation, mercury, vapor pressure.

1. Introduction

Recent concerns about mercury as an industrial pollutant have lead to increased interest in the detection and regulation of mercury in the environment [1]. The development of standardized equations for the thermophysical properties of mercury can aid this task. A critical evaluation of density, thermal expansion coefficients, and compressibilities as a function of temperature and pressure was conducted by Holman and ten Seldam [2]. Bettin and Fehlauer [3] recently reviewed the density of mercury for metrological applications. Vukalovich and Fokin's book [4] and the Gmelin Handbook [5] are both thorough treatises on the thermophysical properties of mercury. Thermal properties such as thermal conductivity and heat capacity were reviewed by Sakonidou et al. [6], while Hensel and Warren [7] cover other properties including optical and magnetic characteristics. To assess risks of exposure, it is important to have an accurate

∗ Physical and Chemical Properties Division, Chemical Science and Technology Laboratory.

representation of the vapor pressure of mercury. Numerous compilations and correlations of the vapor pressure of mercury have been published [8-25], but there is no consensus on which is the best one to use for a given purpose. In this work, we review the existing experimental data and correlations, and provide a new representation of the vapor pressure of mercury that is valid from the triple point to the critical point. We also present comparisons with both experimental data and correlations, and estimate the uncertainty of the correlation.

2. Experimental Vapor Pressure Data

Experimental measurements of the vapor pressure of mercury have a long history. A single vapor pressure point of mercury, the boiling point, was first measured in 1801 by Dalton [26], who obtained a value corresponding to 622 K; shortly thereafter, in 1803, Crichton [27] mentioned that the normal boiling point is above a temperature corresponding to 619 K. More recently, the normal boiling point of mercury was determined by Beattie et al. [28] as (356.58 ± 0.0016) °C, on the 1927 International Temperature Scale. This measurement was selected as a secondary fixed point on the ITS-48 Temperature scale [29]. Converted to the ITS-90 temperature scale [30], this value is (629.7653 ± 0.0016) K. The value recommended by Marsh [31] is 629.81 K (IPTS-68); on the International Practical Temperature Scale [32] of 1968, this was a secondary fixed point. Converted to ITS-90, this recommendation is 629.7683 K for the normal boiling point.

Regnault [33] published observations of the vapor pressure of mercury over a range of temperatures in 1862. Several of the early publications are by researchers who became quite famous, including Avogadro [34], Dalton [26], Hertz [35], Ramsay [36], and Haber [37]. Indeed, much of the work on mercury was done in the early part of the 20th century. Figure 1 shows the distribution of the experimental data. Table 1 gives a detailed compilation of sources of vapor-pressure data from 1862 to the present, along with the temperature range of the measurements, the experimental method used, and an estimate of the uncertainty of these measurements. In general, determinations of the purity of the mercury were not available; however, methods for the purification of mercury have been known for a long time, and samples of high purity were prepared

before it was possible to quantify the purity [18]. The estimates of uncertainty were obtained by considering the experimental method and conditions, the original author's estimates (when available), and agreement with preliminary correlations. These correspond to our estimate of a combined expanded uncertainty with a coverage factor of two. In Appendix A, we tabulate all experimental data for the vapor pressure of mercury collected in this study.

The experimental techniques used to measure vapor pressure can be grouped into three main categories: the static, quasistatic, and kinetic techniques are discussed by Dykyj et al. [38] and Ditchburn and Gilmour [14]. One of the simplest methods to measure the vapor pressure is a static method that involves placing the sample in a closed container, then removing any air and impurities, keeping the vessel at constant temperature, and then measuring the temperature and pressure after equilibrium has been established. It is generally limited to pressures above 10 kPa. In principle, it is applicable to any pressure, but in practice the presence of nonvolatile impurities can cause large systematic errors. With very careful sample preparation, it may be possible to go to lower pressures with this technique. Another static instrument is the isoteniscope. This type of instrument was used by Smith and Menzies [39, 40] in their early work on the vapor pressure of mercury. In this type of apparatus, the sample is placed in a bulb that is connected to a U-tube that acts as a manometer (i.e., a pressure sensor). The device is placed in a thermostat, and the external pressure is adjusted until it equals that of the vapor above the sample. Isoteniscopes are limited by the sensitivity of the pressure sensor. A third type of static method involves the use of an inclined piston gauge. The sample is placed in a cylinder fitted with a movable piston so that the pressure of the sample balances the weight (gravitational force) of the piston. This method is generally applicable over the range 0.1 kPa to 1.5 kPa.

Among the instruments classified as quasistatic are ebulliometers and transpiration methods. In both of them, a steady rate of boiling is established, and it is assumed that the pressure at steady state is equivalent to the equilibrium vapor pressure. In an ebulliometer, the sample is boiled at a pressure set by an external pressurizing gas (often helium) with the vapor passing through a reflux condenser before returning to the boiler. The temperature measured is that of the vapor just above the boiling liquid. An

advantage to this method is that volatile impurities do not condense and are removed at the top of the apparatus. This method may also be set up in a comparative mode with two separate ebulliometers, one containing a reference fluid and the other containing the sample fluid connected with a common pressure line, so that direct measurement of the pressure is unnecessary. It is possible to make very accurate measurements with this type of device, at pressures greater than about 2 kPa. The very accurate measurements of the vapor pressure of mercury by Ambrose and Sprake [18] were made with an ebulliometric technique. The transpiration method (also called gas saturation) involves passing a steady stream of an inert gas over or through the sample, which is held at constant temperature. The pressure is not measured directly, but rather is calculated from converting the concentration of the mercury in the gas stream to a partial pressure that is the vapor pressure of the sample. This type of method has a larger uncertainty than some of the other methods, generally ranging from 0.5 to 5 % [38]. It is most useful over a pressure range of 0.1 to 5 kPa. For example, Burlingame [43] and Dauphinee [49,50] used the transpiration method in their measurements.

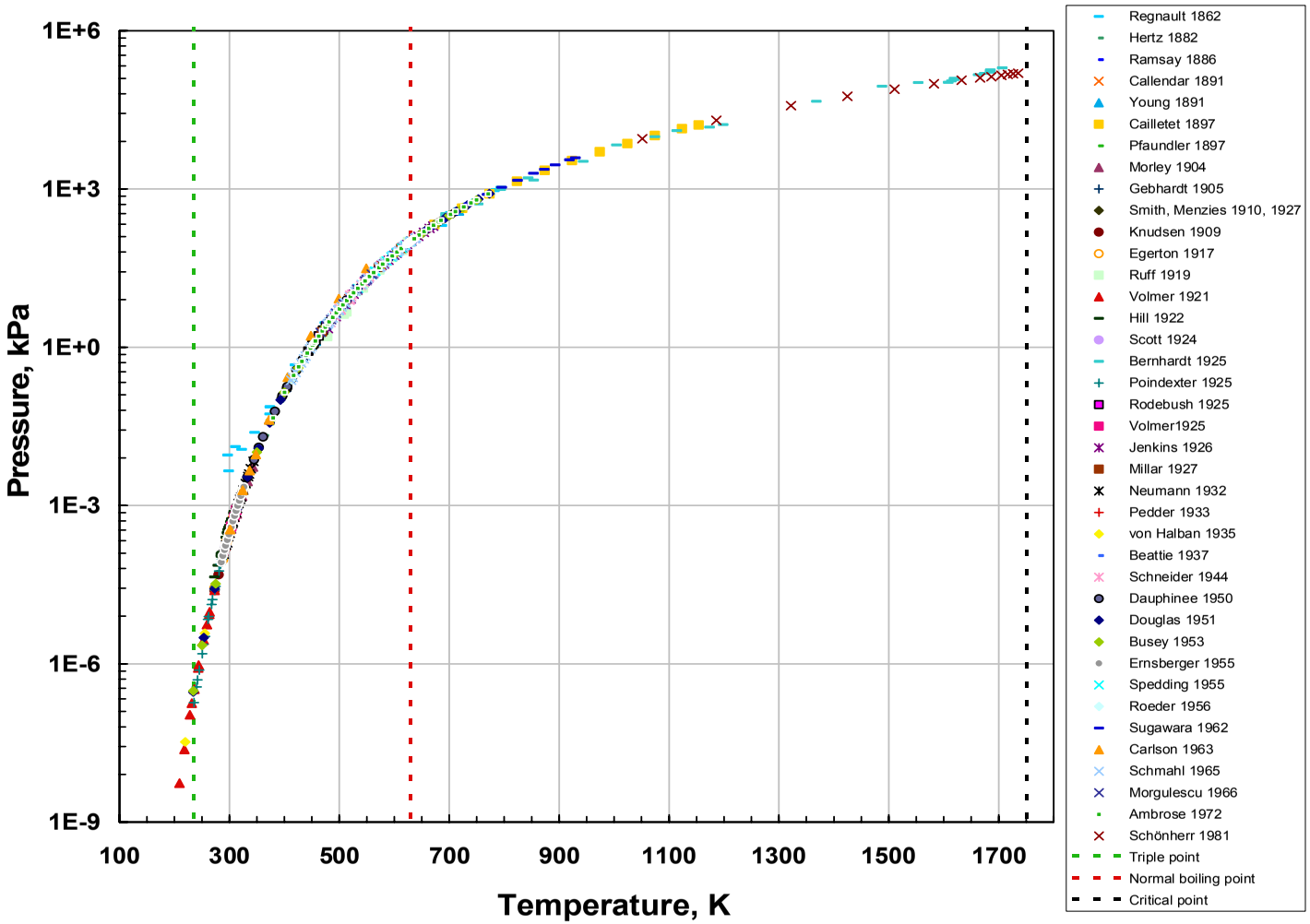


Figure 1. Experimental vapor pressure data for mercury.

Table 1. Summary of available data for the vapor pressure of mercury. References in boldface indicate primary data sets (see text).

First Author	Year	Method	No. pts.	*T* range, K	Estimated uncertainty, %
Ambrose [18]	1972	ebulliometer	113	417-771	less than 0.03, greatest at lowest *T*
Beattie [28]	1937	boiling tube	42	623-636	0.03
Bernhardt [41]	1925	3 static methods	27	694-1706	varies from 2 to >15
Bessel-Hagen [42]	1881	Töpler vacuum pump	2	273-293	>20
Burlingame [43]	1968	transpiration	38	344-409	4
Busey [44]	1953	derived from caloric properties	24	234-750	varies from 0.2 to 3.5 at lowest *T*
Cailletet [45]	1900	Bourdon manometer	11	673-1154	varies from 1 to 7
Callendar [46]	1891	Meyer tube	2	630	0.2
Cammenga [47]	1969	effusion	graphical results	273-325	
Carlson [48]	1963	effusion	9	299-549	varies from 3 to >20
Dauphinee [49, 50]	1950,1951	transpiration	18	305-455	5
Douglas [51]	1951	derived from caloric properties	30	234-773	varies from 0.03 (at normal boiling point) to 1.5 at lowest *T*
Durrans [52]	1920	gives table attributed to Smith and Menzies[39]	46	273-723	
Egerton [53]	1917	effusion	27	289-309	5
Ernsberger [54]	1955	piston manometer	18	285-327	1
Galchenko [55]	1978	static method	graphical results	523-723	3
Galchenko [56]	1984	atomic absorption	correlating equation only	723-873	3
Gebhardt [57]	1905	boiling tube	9	403-483	8
Haber [37]	1914	vibrating quartz filament	1	293	2
Hagen [58]	1882	differential pressure	5	273-473	>20
Hensel [59]	1966	electrical resistance	graphical results	1073-critical	not available
Hertz [35]	1882	static absolute manometer	9	363-480	5
Heycock [60]	1913	not available	1	630	0.2
Hildenbrand [61]	1964	torsion-effusion	6	295-332	5
Hill [62]	1922	radiometer principle	19	272-308	30
Hubbard [63]	1982	static	graphical results	742-1271	not available
Jenkins [64]	1926	isoteniscope	21	479-671	0.1 to >20
Kahlbaum [65]	1894	ebulliometer	43	393-493	>10
Knudsen [66]	1909	effusion	10	273-324	varies from 5 to 10
Knudsen [67]	1910	radiometer principle	7	263-298	varies from 5 to 10

Table 1. Continued.

First Author	Year	Method	No. pts.	*T* range, K	Estimated uncertainty, %
Kordes [68]	1929	temperature scanning evaporation method	2	630-632	4
Mayer [69]	1930	effusion	82	261-298	5, except greater at $T<270$
McLeod [70]	1883	transpiration	1	293	>20
Menzies [39, 40]	1910,1927	isoteniscope	46	395-708	0.5
Millar [71]	1927	isoteniscope	6	468-614	2
Morley [72]	1904	transpiration	6	289-343	varies from 8 to >20
Murgulescu [73]	1966	quasi-static	9	301-549	3
Neumann [74]	1932	torsion balance	19	290-344	6
Pedder [75]	1933	transpiration	3	559-573	2
Pfaundler [76]	1897	gas saturation	3	288-372	12
Poindexter [77]	1925	ionization gage	17*	235-293	5-20, greatest at lowest *T*
Raabe [78]	2003	computer simulation	20	408-1575	varies from 0.5 to >20
Ramsay [36]	1886	isoteniscope	13	495-721	varies from 0.3 to 10 at highest *T*
Regnault [33]	1862	isoteniscope	29	297-785	~6 for $T>400$, much higher for lower *T*
Rodebush [79]	1925	quasi-static	7	444-476	1
Roeder [80]	1956	quartz spiral manometer	7	413-614	2
Ruff [81]	1919	temperature scanning evaporation method	12	478-630	>20
Schmahl [82]	1965	static method	43	412-640	1.5
Schneider [83]	1944	gas saturation	23	484-575	10
Schönherr [84]	1981	electrical conductivity	13	1052-1735	3
Scott [85]	1924	vibrating quartz filament	1	293	2
Shpil'rain [86]	1971	ebulliometer	50	554-883	0.6 to 0.8
Spedding [87]	1955	isoteniscope	13	534-630	0.03
Stock [88]*	1929	transpiration	3	253-283	20
Sugawara [9]	1962	static method	14	602-930	2
van der Plaats [89]	1886	transpiration	26	273-358	
Villiers [90]	1913	ebulliometer	12	333-373	6
Volmer [91]	1925	effusion	10	303-313	3
von Halban [92]	1935	resonance light absorption	1*	255	7
Young [93]	1891	static	11	457-718	2

* Excludes points below the triple point.

The Knudsen effusion method is a type of vapor pressure measurement classified as a dynamic method. In this type of experiment, a steady rate of evaporation through an orifice into a vacuum is established, and pressure is calculated from the flow rate through the orifice by use of kinetic theory. This method is applicable at very low pressures (below 0.1 kPa), but generally has high uncertainties.

As indicated in Table 1, many measurements have been made on the vapor pressure of mercury. However, only a limited number of these are comprehensive and have uncertainty levels of one percent or less. These sets have been identified as primary data sets in our work and are indicated by boldface type in Table 1. In general, the most accurate measurements were those made with ebulliometric methods. Ambrose and Sprake [18] used an ebulliometric technique for their measurements from 380 K to 771 K. These data have an uncertainty of about 0.03 % or lower, with the largest uncertainty at the lowest temperatures. Beattie et al. [28] very accurately determined the boiling point of mercury over the temperature range 623 K to 636 K. Spedding and Dye [87] used an isoteniscope to measure the vapor pressure over the range 534 K to 630 K, with uncertainties on the order of 0.03 % except at the lowest temperatures where they are larger. Menzies [40, 94] used an isoteniscope at temperatures from 395 K to 708 K, but these data show more scatter and have larger uncertainties than the sets mentioned above; however, the uncertainties are still less than 0.5 %. Shpil'rain and Nikanorov [86] used an ebulliometric method extending from 554 K to 883 K. Their data are more consistent with the measurements of Ambrose and Sprake [18] in their region of overlap than are other high temperature sets, such as those by Sugawara et al. [9] , Bernhardt [41] or Cailletet et al. [45], and thus were selected as the primary data for the high temperature region from about 700 K to 900 K. In addition, although the uncertainty is higher than 1 %, we have selected the data of Schönherr and Hensel [84] for the highest temperature region, 1052 K to 1735 K. This data set was obtained by observing changes in the electrical conductivity. At fixed pressures, the temperature was raised, and when a discontinuity was observed, this was taken as an indication of phase change.

All of the sets mentioned so far are for temperatures greater than 380 K. At lower temperatures, the measurements are much more uncertain and display significant scatter. In the low temperature range, we considered the measurements of Ernsberger and Pitman [54]

to be the most accurate. These measurements were made with an absolute manometer method, with uncertainties on the order of 1 %, and they cover the temperature range 285 K to 327 K. This data set has been adopted in the metrology community for use in precision manometry, and has been described as reliable and confirmed by heat capacity measurements [95]. The reliability and thermodynamic consistency of these data will be discussed in more detail in a later section of this document.

The end points of the vapor pressure curve for stable vapor-liquid equilibrium are the triple point and the critical point. Metastable points may be obtained at points below the triple point. In principle, the three phase-boundary curves that meet at the gas-liquid-solid triple point of a pure substance continue beyond this intersection so that the phase equilibria become metastable relative to the third phase, which is absolutely stable. Vapor-liquid equilibrium along the vapor pressure curve continued below the triple point becomes metastable relative to the solid phase, and vapor-solid equilibrium along the sublimation pressure curve continued above the triple point becomes metastable relative to the liquid phase. Although the former has been realized in experiments [96], metastable phase equilibria are one of the least investigated phenomena of the behavior of matter. Their existence in principle is mentioned here because three datasets in the present collection report mercury vapor pressure data at temperatures below the triple point: Poindexter [77], Stock and Zimmermann [88], and von Halban [92]. The farthest reaching data below the triple point temperature are the results of Poindexter, covering a range from 194 K to 293 K. However, in this work we restrict our study to points above the triple point, although all points are tabulated in Appendix A.

The triple point of mercury has been designated as a fixed point of the ITS-90 [30] temperature scale, with a value of 234.3156 K. The critical point has been measured by several investigators; these values are listed in Table 2, along with uncertainty estimates provided by the authors. One of the first measurements of the critical point was made by Koenigsberger [97] in 1912, who made visual observations in a quartz tube and reported the critical temperature of mercury to be near 1270 °C (1543 K). This measurement was later criticized by Menzies [94] who reported that the critical temperature was at least 1275 °C (1548 K). Another early determination was that of Bernhardt [41] who extrapolated his vapor pressure observations, and used Bender's [98] value of 1650 °C (1923 K) for the critical

temperature, while estimating the critical pressure to be in the range 294.2 to 343.2 MPa. Later, Birch [99] determined the critical point by observing the changes in electrical resistance as a function of temperature at constant pressure. The review paper of Mathews [100] adopted Birch's values for the critical point. Ambrose [101] and also Vargaftik et al. [8] instead selected the value obtained by Franck and Hensel [102], also obtained from studies of changes in electrical resistance. Kikoin and Senchenkov [103] used electrical conductivity experiments to locate the critical point, Neale and Cusack [104] observed changes in the Seebeck voltage, while Götzlaff [13] analyzed isochoric and isobaric PVT data extrapolated to the saturation boundary. Most recently Kozhevnikov et al. [105] observed changes in the speed of sound along isobars as a function of temperature to determine the critical point. The value by Bernhardt [41] is too high both in pressure and in temperature. The critical temperature of Franck and Hensel [102] agrees very well with that obtained by Kozhevnikov et al. [105], while the critical pressure of Götzlaff [13] agrees very well with that of Kozhevnikov et al. [105] In this work we adopted the critical point of Kozhevnikov et al. [105].

Table 2. The critical temperature and pressure of mercury.*

First Author	Year	T_c (K)	p_c (MPa)
Koenigsberger [97]	1912	~1543	
Menzies [94]	1913	>1548	
Bender [98]	1915	1923	
Meyer [106]	1921	1747	
Bernhardt [41]	1925	1923	294.2 - 343.2
Birch [99]	1932	1733 ± 20	161 ± 5
Franck [59, 102]	1966	1763.15 ± 15	151 ± 3
Kikoin [103]	1967	1753 ± 10	152 ± 1
Neale [104]	1979	1768 ± 8	167.5 ± 2.5
Hubbard [107]	1983	1750	172
Götzlaff [13]	1988	1751 ± 1	167.3 ± 0.2
Kozhevnikov [105]	1996	1764 ± 1	167 ± 3

*Uncertainties are expressed in kelvins and megapascals for the temperature and pressure, respectively.

3. Correlation Development

Numerous expressions have been used to represent the vapor pressure of a pure fluid; many are reviewed in Růžička and Majer [108]. Equations of the general form

$$ln(p/p_c) = (T_c/T)\sum_i a_i \tau^{i/2} \quad , \tag{1}$$

where $\tau = 1\text{-}T/T_c$, are attributed to Wagner [109-112] and have been used successfully to represent the vapor pressures of a wide variety of fluids. Lemmon and Goodwin [113] used the Wagner form with exponents (1, 1.5, 2.5, and 5) to represent the vapor pressures of normal alkanes up to C_{36}. This form, which we will call Wagner 2.5-5, is one of the most widely used forms along with the equation with exponents (1, 1.5, 3, and 6) [109, 110], which we call Wagner 3-6. The 2.5-5 form has emerged as the generally preferred form [114]. When the data set is extensive and of high quality, other forms with alternative sets of exponents with additional terms have been used. For example, a Wagner equation with exponents (1, 1.5, 2, 2.5, and 5.5) was used to represent the vapor pressure of acetonitrile [115], and another variant of the Wagner equation, with exponents (1, 1.89, 2, 3, and 3.6), was used to represent the vapor pressure of heavy water [116] from the triple point to the critical point to within the experimental scatter of the measurements. The International Association for the Properties of Water and Steam (IAPWS) formulation for the vapor pressure of water [117, 118] uses a six-term Wagner equation with exponents of (1, 1.5, 3, 3.5, 4, and 7.5).

Since there is a lack of high-quality experimental vapor-pressure data in the low temperature region ($T < 285$ K), liquid heat capacity measurements at low temperatures can be used to supplement the vapor-pressure data [108, 114, 119]. This permits the simultaneous regression of heat capacity and vapor-pressure data to determine the coefficients of a vapor pressure equation that is valid down to the triple point. An alternative method is to use an expression involving enthalpies of vaporization in addition to vapor-pressure data [120]. Both of these approaches can be used to ensure that the vapor pressure is thermodynamically consistent with other thermodynamic data.

King and Al-Najjar [119] related heat capacity and vapor pressure using

$$\frac{d}{dT}\left(T^2\,\frac{d\ln p_{sat}}{dT}\right)=\frac{C_p^0-C_p^L-G}{R}\quad , \tag{2}$$

where $C_p°$ and C_p^{L} are the heat capacities at constant pressure of the ideal gas and the saturated liquid, R is the molar gas constant [121] R=8.314 472 J/(mol·K), p_{sat} is the vapor pressure, and G represents vapor phase nonidealities and is given by

$$G=T\left(p_{sat}\frac{d^2B}{dT^2}+2\frac{dp_{sat}}{dT}\left(\frac{dB}{dT}-\frac{dV_L}{dT}\right)+\frac{d^2p_{sat}}{dT^2}\left(B-V_L\right)\right). \tag{3}$$

In this expression, B is the second virial coefficient and V_{L} is the molar volume of the liquid. We restrict the use of this equation to temperatures lower than 270 K, where vapor pressures are on the order of 10^{-5} kPa. In this region, we treat the gas phase as ideal so that the G term may be neglected. (For example, we applied equations in Douglas et al. [51] for the virial coefficients, liquid volumes, heat capacities, vapor pressures and their derivatives, and estimated that the magnitude of the term G at 270 K relative to the heat capacity difference in eq (2) is on the order 10^{-4} %.) Assuming that mercury can be considered as an ideal monatomic gas for these low pressures, the ideal gas heat capacity for mercury is $C_p° = 5R/2$ [122]. With these assumptions, after the derivatives of the vapor pressure in eq (2) are taken analytically incorporating the specific form of the vapor pressure correlation function of eq (1), one obtains the simple expression $(5R/2 - C_p^{\mathrm{L}})/R = (T/T_{\mathrm{c}})\Sigma a_i(i/2)(i/2 - 1)\tau^{i/2-1}$.

Busey and Giauque [44] measured the heat capacity C_{p} of mercury from 15 to 330 K with estimated uncertainties of 0.1 %. Amitin et al. [123] also measured the heat capacity of mercury at temperatures from 5 K to 300 K, with an estimated uncertainty of 1 %. The smoothed data over the temperature range 234 K to 270 K from these two sources were identified as primary data for use in the regression, in addition to the primary vapor pressure data discussed above. The smoothed heat capacity data from these two sources are listed in Appendix B.

For our analysis of both p_{sat} and C_{p} experimental data, all temperatures were first converted to the ITS-90 scale. Data taken prior to 1927 were converted to ITS-90 assuming

that the older data were on the International Temperature Scale of 1927, although we realize this introduces additional uncertainties. Except for the data of Menzies [40], all primary data were measured after 1927. The temperatures of the data of Menzies were first converted to the 1948 temperature scale by use of the procedure given by Douglas et al. [51] and then were converted to ITS-90.

We regressed the primary data set to three different Wagner-type expressions: the 3-6, the 2.5-5, and a variable exponent expression where the exponents were selected from a bank of terms by use of a simulated annealing procedure [124, 125]. Simulated annealing is an optimization technique that can be used in complex problems where there may be multiple local minima. It is a combinatorial method that does not require derivatives and does not depend upon "traveling downhill"; it also is relatively easy to implement. An example program using the simulated annealing to solve the Traveling Salesman Problem is given in the book by Press et al. [125]. In this work, the search space contained a bank of terms where the bank contained exponents with powers of τ in increments of 0.5, with terms up to τ^{12}. We followed the recommendation of Harvey and Lemmon [116] and required the equation to contain terms of order 1, 1.89, and 2, based on theoretical considerations on the behavior near the critical point. The simulated annealing algorithm was used to determine the optimal terms from the bank of terms. We implemented a Lundy and Mees [126] annealing schedule, similar to that of earlier work [127]. During the regression, one can treat the critical pressure as a variable to be determined in the regression, or it can be fixed. Due to concerns about the quality and amount of experimental data in the temperature range 930 K to 1764 K, we adopted the critical point of Kozhevnikov et al. [105] rather than determining it by fitting experimental data. The minimization was done with orthogonal distance regression using the NIST statistical package ODRPACK [128]. For the regression, the data were weighted according to their estimated uncertainty (u) with weights of $1/u^2$. In addition, the vapor pressure data were given a relative weight factor of one, and the heat capacity data a relative weight factor of 0.02. Points that deviated by more than three standard deviations from preliminary fits were considered outliers and were not included in the statistics and final regression.

The 2.5-5 form of the Wagner equation provided a better fit of the primary data set than the 3.0-6 form; further improvement resulted from the use of the simulated annealing

algorithm. Upon closer inspection, we noted that although one could reasonably reproduce the numerical value of the heat capacity, it was not possible to reproduce well the slope of the saturated liquid heat capacity near the triple point without degrading the fit in other regions. We note that the liquid heat capacity at saturation of mercury as a function of temperature displays an interesting behavior—a distinct minimum in the curve is observed below the normal boiling point, as shown in Figure 2. Douglas et al. [51] noted that other liquid metals such as sodium and potassium also exhibit this behavior. Among nonmetals, we observe that water displays this feature; however, it is not observed in simple hydrocarbons such as linear alkanes. In order to simultaneously fit the vapor pressure and liquid heat capacity data, and have the correct behavior of the slope of the heat capacity as a function of temperature along the saturation boundary, we increased the number of terms in the regression from 5 to 6 and used the simulated annealing algorithm to obtain our final equation,

$$ln(p/p_c) = (T_c/T)\left(a_1\tau + a_2\tau^{1.89} + a_3\tau^2 + a_4\tau^8 + a_5\tau^{8.5} + a_6\tau^9\right). \quad (4)$$

The regressed coefficients and their standard deviations are given in Table 3a, and fixed parameters for eq (4) are given in Table 3b. Table 4 gives sample values of the vapor pressure calculated from eq (4) over the temperature range 273.15 to 333.15 K. For validation of computer code, more digits than are statistically meaningful are given. For the calibration community, we also have included in Table 4 the density of saturated mercury vapor in moles per liter and nanograms per milliliter obtained assuming the ideal gas law applies, $\rho = p/(R \cdot T)$. We use the currently accepted values of the molar gas constant [121] R = 8.314 472 J/(mol·K) and the relative atomic mass [129] of mercury, 200.59 g/mol.

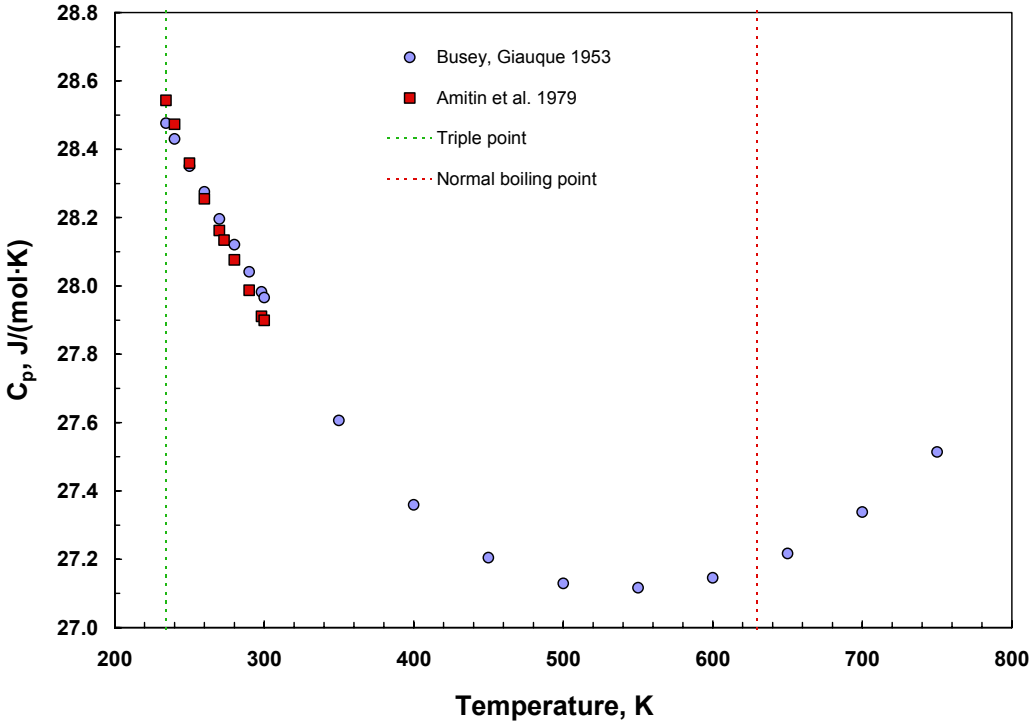


Figure 2. Temperature dependence of the heat capacity of saturated liquid mercury.

Table 3a. Fitted values of the parameters in eq (4) and their standard deviations.

i	a_i	**Std. dev.**
1	- 4.576 183 68	0.0472
2	-1.407 262 77	0.8448
3	2.362 635 41	0.8204
4	-31.088 998 5	1.3439
5	58.018 395 9	2.4999
6	-27.630 454 6	1.1798

Table 3b. Fixed parameters in eq (4).

T_c **(K)**	p_c **(MPa)**
1764	167

Table 4. Vapor pressure of mercury calculated with eq (4) from 273 K to 333 K.

T, K	t, °C	p, MPa	Ideal gas density,† mol/L	Ideal gas density,† ng/mL	T, K	t, °C	p, MPa	Ideal gas density,† mol/L	Ideal gas density,† ng/mL
273.15	0	$2.698829\cdot10^{-8}$	$1.188337\cdot10^{-8}$	2.383684	304.15	31	$4.259045\cdot10^{-7}$	$1.684185\cdot10^{-7}$	33.78306
274.15	1	$2.979392\cdot10^{-8}$	$1.307088\cdot10^{-8}$	2.621887	305.15	32	$4.611495\cdot10^{-7}$	$1.817581\cdot10^{-7}$	36.45885
275.15	2	$3.286720\cdot10^{-8}$	$1.436675\cdot10^{-8}$	2.881826	306.15	33	$4.990473\cdot10^{-7}$	$1.960527\cdot10^{-7}$	39.32620
276.15	3	$3.623129\cdot10^{-8}$	$1.577990\cdot10^{-8}$	3.165289	307.15	34	$5.397770\cdot10^{-7}$	$2.113631\cdot10^{-7}$	42.39732
277.15	4	$3.991118\cdot10^{-8}$	$1.731989\cdot10^{-8}$	3.474196	308.15	35	$5.835283\cdot10^{-7}$	$2.277535\cdot10^{-7}$	45.68508
278.15	5	$4.393376\cdot10^{-8}$	$1.899698\cdot10^{-8}$	3.810605	309.15	36	$6.305024\cdot10^{-7}$	$2.452917\cdot10^{-7}$	49.20305
279.15	6	$4.832795\cdot10^{-8}$	$2.082217\cdot10^{-8}$	4.176720	310.15	37	$6.809117\cdot10^{-7}$	$2.640489\cdot10^{-7}$	52.96556
280.15	7	$5.312487\cdot10^{-8}$	$2.280723\cdot10^{-8}$	4.574903	311.15	38	$7.349813\cdot10^{-7}$	$2.841004\cdot10^{-7}$	56.98770
281.15	8	$5.835798\cdot10^{-8}$	$2.496477\cdot10^{-8}$	5.007682	312.15	39	$7.929493\cdot10^{-7}$	$3.055255\cdot10^{-7}$	61.28535
282.15	9	$6.406319\cdot10^{-8}$	$2.730825\cdot10^{-8}$	5.477762	313.15	40	$8.550671\cdot10^{-7}$	$3.284075\cdot10^{-7}$	65.87527
283.15	10	$7.027907\cdot10^{-8}$	$2.985209\cdot10^{-8}$	5.988031	314.15	41	$9.216005\cdot10^{-7}$	$3.528344\cdot10^{-7}$	70.77506
284.15	11	$7.704698\cdot10^{-8}$	$3.261169\cdot10^{-8}$	6.541579	315.15	42	$9.928302\cdot10^{-7}$	$3.788986\cdot10^{-7}$	76.00327
285.15	12	$8.441128\cdot10^{-8}$	$3.560348\cdot10^{-8}$	7.141702	316.15	43	$1.069052\cdot10^{-6}$	$4.066972\cdot10^{-7}$	81.57939
286.15	13	$9.241950\cdot10^{-8}$	$3.884501\cdot10^{-8}$	7.791920	317.15	44	$1.150580\cdot10^{-6}$	$4.363324\cdot10^{-7}$	87.52391
287.15	14	$1.011225\cdot10^{-7}$	$4.235498\cdot10^{-8}$	8.495986	318.15	45	$1.237743\cdot10^{-6}$	$4.679116\cdot10^{-7}$	93.85838
288.15	15	$1.105749\cdot10^{-7}$	$4.615334\cdot10^{-8}$	9.257899	319.15	46	$1.330888\cdot10^{-6}$	$5.015475\cdot10^{-7}$	100.6054
289.15	16	$1.208348\cdot10^{-7}$	$5.026135\cdot10^{-8}$	10.08192	320.15	47	$1.430383\cdot10^{-6}$	$5.373585\cdot10^{-7}$	107.7888
290.15	17	$1.319646\cdot10^{-7}$	$5.470161\cdot10^{-8}$	10.97260	321.15	48	$1.536613\cdot10^{-6}$	$5.754690\cdot10^{-7}$	115.4333
291.15	18	$1.440308\cdot10^{-7}$	$5.949822\cdot10^{-8}$	11.93475	322.15	49	$1.649985\cdot10^{-6}$	$6.160093\cdot10^{-7}$	123.5653
292.15	19	$1.571046\cdot10^{-7}$	$6.467678\cdot10^{-8}$	12.97352	323.15	50	$1.770928\cdot10^{-6}$	$6.591162\cdot10^{-7}$	132.2121
293.15	20	$1.712619\cdot10^{-7}$	$7.026452\cdot10^{-8}$	14.09436	324.15	51	$1.899890\cdot10^{-6}$	$7.049329\cdot10^{-7}$	141.4025
294.15	21	$1.865835\cdot10^{-7}$	$7.629036\cdot10^{-8}$	15.30308	325.15	52	$2.037347\cdot10^{-6}$	$7.536097\cdot10^{-7}$	151.1666
295.15	22	$2.031558\cdot10^{-7}$	$8.278502\cdot10^{-8}$	16.60585	326.15	53	$2.183795\cdot10^{-6}$	$8.053040\cdot10^{-7}$	161.5359
296.15	23	$2.210708\cdot10^{-7}$	$8.978112\cdot10^{-8}$	18.00919	327.15	54	$2.339760\cdot10^{-6}$	$8.601806\cdot10^{-7}$	172.5436
297.15	24	$2.404265\cdot10^{-7}$	$9.731323\cdot10^{-8}$	19.52006	328.15	55	$2.505789\cdot10^{-6}$	$9.184118\cdot10^{-7}$	184.2242
298.15	25	$2.613271\cdot10^{-7}$	$1.054180\cdot10^{-7}$	21.14581	329.15	56	$2.682462\cdot10^{-6}$	$9.801783\cdot10^{-7}$	196.6140
299.15	26	$2.838837\cdot10^{-7}$	$1.141344\cdot10^{-7}$	22.89423	330.15	57	$2.870385\cdot10^{-6}$	$1.045669\cdot10^{-6}$	209.7507
300.15	27	$3.082141\cdot10^{-7}$	$1.235036\cdot10^{-7}$	24.77358	331.15	58	$3.070193\cdot10^{-6}$	$1.115081\cdot10^{-6}$	223.6740
301.15	28	$3.344440\cdot10^{-7}$	$1.335691\cdot10^{-7}$	26.79262	332.15	59	$3.282555\cdot10^{-6}$	$1.188620\cdot10^{-6}$	238.4253
302.15	29	$3.627066\cdot10^{-7}$	$1.443770\cdot10^{-7}$	28.96059	333.15	60	$3.508170\cdot10^{-6}$	$1.266503\cdot10^{-6}$	254.0478
303.15	30	$3.931433\cdot10^{-7}$	$1.559763\cdot10^{-7}$	31.28729					

† Assumes ideal gas law applies.

4. Comparison with Experimental Data

For the 294 vapor pressure points in the primary data set, the average absolute deviation is 0.14 %, the bias is –0.028 %, and the root mean square deviation is 0.35 % where we use the definitions AAD = $(100/n)\Sigma\text{abs}(p_i^{\text{calc}}/ p_i^{\text{expt}} - 1)$, BIAS = $(100/n)$ $\Sigma(p_i^{\text{calc}}/ p_i^{\text{expt}} - 1)$, and $\text{RMS}^2 = (100/n)(\Sigma(p_i^{\text{calc}}/ p_i^{\text{expt}} - 1)^2 - ((100/n) \Sigma(p_i^{\text{calc}}/ p_i^{\text{expt}} - 1))^2$, where n is the number of points. The AAD and RMS for the primary data are given in Table 5. The normal boiling point calculated by this equation is 629.7705 K.

Figure 3 compares the primary data set with our correlation, eq (4). The data of Ernsberger and Pitman [54] display substantial scatter, but the results are within their estimated experimental uncertainty of 1 %. The data of Shpil'rain and Nikanorov [86] also display a fairly high scatter, but again it is within their uncertainty estimate (0.6 % to 0.8 %). The very accurate measurements of Beattie et al. [28] are in the vicinity of the normal boiling point, and the correlation, eq (4), indicates an uncertainty of 0.02 %, at a coverage factor of 2. The measurements of Spedding and Dye [87] and those of Ambrose and Sprake [18] also are represented well by our correlation, although the lowest temperature points display larger scatter than at higher temperatures. The measurements of Menzies [39, 40] are also represented to within their estimated uncertainty. The highest temperature data of Schönherr and Hensel [84] are represented with an AAD of 1 % and a standard deviation of 1.4 %; several points are outside of the range of the plot and are not shown. The correlation is valid to the critical point at 1764 K, but does not account for a metal-nonmetal transition [63] in mercury at approximately 1360 K that results in a change of slope in the vapor pressure curve.

Table 5. Summary of comparisons of the correlation with the primary data for the vapor pressure of mercury.

First author	No. pts.	*T* range, K	Estimated uncertainty, %	AAD %	RMS %
Ambrose [18]	113*	417-771	less than 0.03, greatest at lowest *T*	0.02	0.06
Beattie [28]	42	623-636	0.03	0.01	0.01
Ernsberger [54]	18	285-327	1	0.33	0.35
Menzies [39, 40]	46**	395-708	0.5	0.14	0.20
Schönherr [84]	13	1052-1735	3	1.06	1.42
Shpil'rain [86]	50	554-883	0.6-0.8	0.25	0.29
Spedding [87]	13	534-630	0.03	0.05	0.06

* Two outliers at 380 K and 400 K were not included in statistics.
** One outlier at 395 K was not included in statistics.

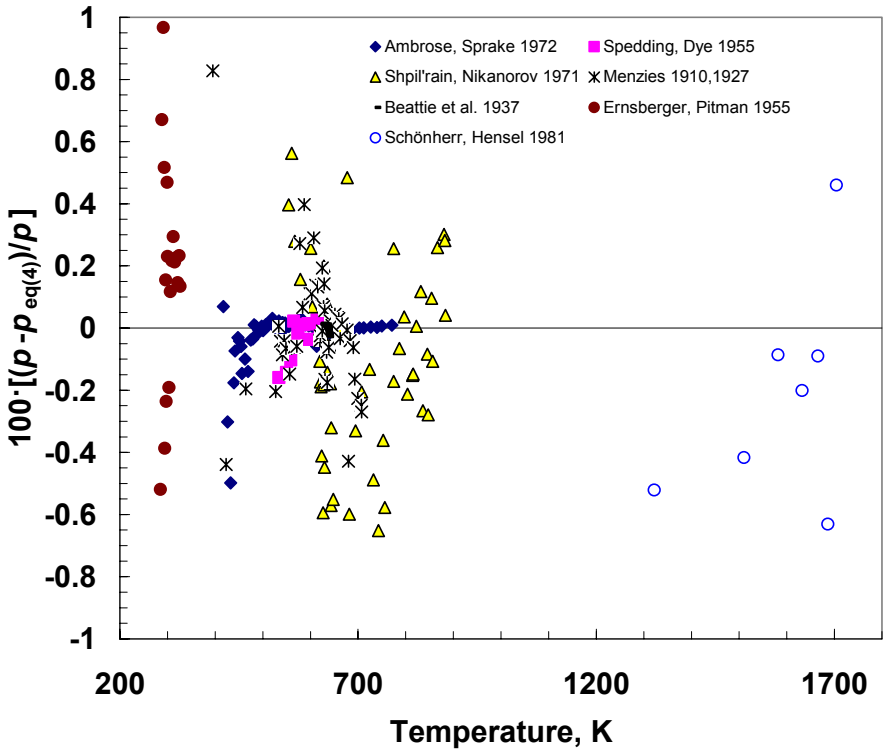


Figure 3. Deviations between the correlation given in eq (4) and the primary data set.

Figure 4 compares selected data not used in the regression (secondary data) with the correlation eq (4), and Table 6 summarizes comparisons with all secondary data. It is interesting to note that the behavior of the correlation at low temperatures falls in between the values of Douglas et al. [51] and those of Busey and Giauque [44]. Both of these sets were not obtained from direct vapor pressure measurements, but rather were calculated based upon caloric measurements combined with vapor pressure data at higher temperatures. The data of Schmahl et al. [82] cover a range of temperature from 412 to 640 K and are in good agreement with the correlation. The measurements of Burlingame [43] and of Dauphinee [49,50] were made by use of a transpiration technique with uncertainties on the order of 4 to 5 %, and the correlation represents them within this range of deviations. Figure 4 also displays considerably more scatter at both the high and low temperature ends of the plot.

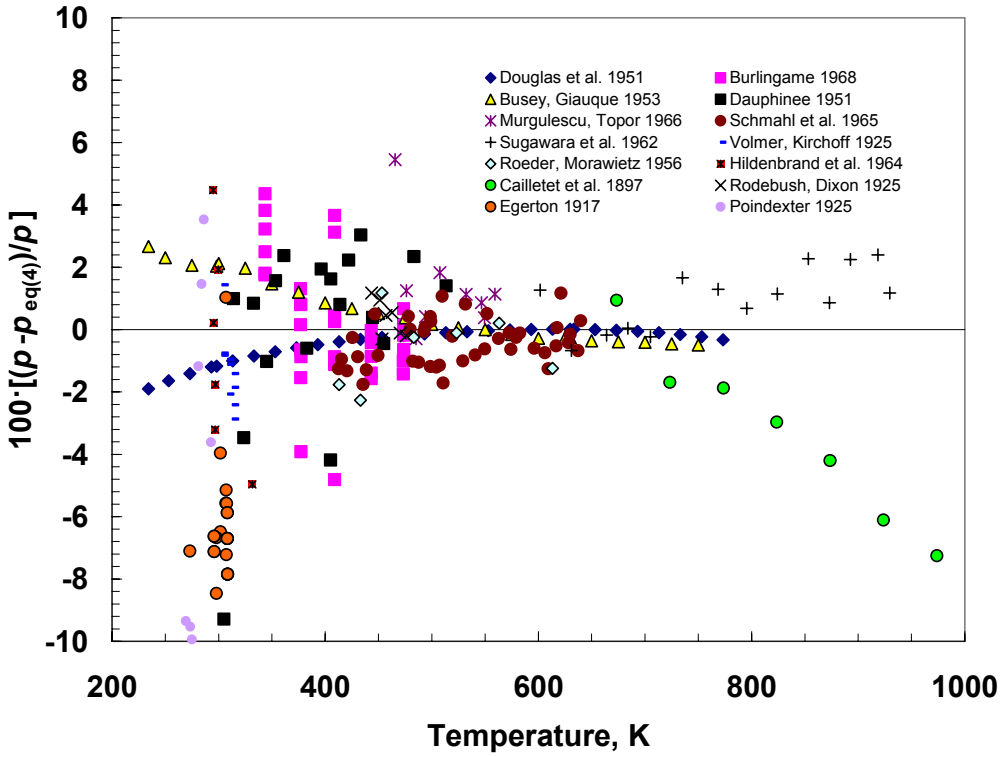


Figure 4. Deviations between the correlation given in eq (4) and selected secondary data.

Table 6. Summary of comparisons of the correlation given in eq (4) with secondary data for the vapor pressure of mercury.

First author	No. pts.	*T* range, K	Estimated uncertainty, %	AAD %	RMS %
Bernhardt [41]	27	694-1706	varies from 2 to >15	14.13	17.26
Bessel-Hagen [42]	2	273-293	>20	96.12	2.50
Burlingame [43]	38	344-409	4	1.44	1.92
Busey [44]	24	234-750	varies from 0.2 to 3.5 at lowest *T*	0.90	1.03
Cailletet [45]	11	673-1154	varies from 1 to7	3.97	2.26
Callendar [46]	2	630	0.2	0.17	0.14
Cammenga [47]	graphical results	273-325			
Carlson [48]	9	299-549	varies from 3 to >20	19.74	16.83
Dauphinee [49, 50]	18	305-455	5	2.14	2.94
Douglas [51]	30	234-773	var. from 0.03 (at normal boiling point) to 1.5 at lowest *T*	0.45	0.54
Durrans [52]	19	290-344		4.63	3.06
Egerton [53]	27*	289-309	5	6.99	2.34
Galchenko [55]	graphical results	523-723	3	na	na
Gebhardt [57]	9	403-483	8	3.34	4.03
Haber [37]	1	293	2	1.84	na
Hagen [58]	5	273-473	>20	51.02	57.44
Hensel [59]	graphical results	1073-critical	na	na	na
Hertz [35]	9	363-480	5	4.50	1.94
Heycock [60]	1	630	0.2	0.21	Na
Hildenbrand [61]	6	295-332	5	2.76	3.16
Hill [62]	19	272-308	30	29.40	4.38
Hubbard [63]	graphical results	742-1271	na	na	na
Jenkins [64]	21	479-671	varies from 0.1 to >20	5.08	5.67
Kahlbaum [65]	43	393-493	>10	8.89	9.47
Knudsen [66]	10	273-324	varies from 5 to 10	7.36	1.67
Knudsen [67]	7	263-298	varies from 5 to 10	7.12	7.64
Kordes [68]	2	630-632	4	2.59	1.84
Mayer [69]	82	261-298	5, except greater at *T*<270	6.72	8.86
McLeod [70]	1	293	>20	77.65	na
Millar [71]	6	468-614	2	1.27	1.84
Morley [72]	6	289-343	varies from 8 to >20	17.58	11.82
Murgulescu [73]	9	301-549	3	1.41	1.56
Neumann [74]	19	290-344	6	4.63	3.06
Pedder [75]	3	559-573	2	1.14	0.94
Pfaundler [76]	3	288-372	12	8.06	5.76
Poindexter [77]	17	235-293	>5-20; greatest at lowest *T*	28.23	29.19
Ramsay [36]	13	495-721	varies from 0.3 to 10 at highest *T*	3.23	3.02
Regnault [33]	29	297-785	~6 for *T*>400, much higher for lower *T*	24.74	34.03
Rodebush [79]	7	444-476	1	0.53	0.54

Table 6. Continued.

First author	No. pts.	*T* range, K	Estimated uncertainty, %	AAD %	RMS %
Roeder [80]	7	413-614	2	1.00	1.11
Ruff [81]	12	478-630	>20	22.49	25.78
Schmahl [82]	43	412-640	1.5	0.70	0.71
Schneider [83]	23	484-575	10	4.04	5.02
Scott [85]	1	293	2	1.11	na
Stock [88]	3	253-283	20	15.05	16.80
Sugawara [9]	14	602-930	2	1.15	0.95
van der Plaats [89]	26	273-358		86.65	23.03
Villiers [90]	12	333-373	6	4.76	3.24
Volmer [91]	10	303-313	3	1.57	1.13
von Halban [92]	2	220-255	7	8.15	2.21
Young [93]	11	457-718	2	1.40	1.30

* One outlier at 288.6 K was not included in statistics. na: not applicable

5. Comparisons with Correlations from the Literature

Figures 5a and 5b compare correlations and tables for the vapor pressure of mercury in different temperature regions obtained in the literature. In these figures we define percent deviation as $100\cdot(p_{eq4}-p_{corr})/p_{eq4}$, where p_{corr} is the vapor pressure from correlations in the literature and p_{eq4} is that obtained from eq (4). We also show the estimated uncertainty band of the new correlation, eq (4), by a heavy black line. The existing correlations in the literature agree well with each other and with the new correlation in the intermediate temperature region from about 400 K to the normal boiling point. In this region, there is a fair number of high quality experimental data. At low temperatures, the existing correlations differ from each other and some differ from the new correlation. As mentioned earlier, there is a paucity of high quality direct vapor-pressure measurements in this region, and we feel that simultaneously using low temperature heat capacity data allows our new correlation to display the proper behavior in the low temperature region. We also had access to newer data that some of the earlier correlations did not include. For example, the Lange's Handbook correlation [130] is based upon the International Critical Tables of 1928 [131], while the most recent CRC Handbook [132] values are based upon Vargaftik et al. [8], which itself is based upon the 1972 book of Vukalovich and Fokin [4]. Some earlier editions of the CRC Handbook (for example the 57th Ed., 1976-1977, p. D-182) used the values from the International Critical Tables of 1928 [131]. Few correlations are applicable for higher temperatures. The maximum temperature limit of the Korea Thermophysical Properties Databank correlation, KDB [133], is given as 654.15 K. The maximum of the PTB equation [22] is 930 K; these correlations should not be extrapolated outside of their given ranges. At the highest temperatures, there are considerable differences among the various correlations; however, there is also a lack of experimental measurements in this region. The de Kruif correlation [20, 21] does not specifically state the temperature limits of the correlation, but the very thorough literature survey in the thesis [20] indicates that the only high temperature data used in their work were those of Bernhardt [41] and Cailletet et al. [45], and they did not have access to the more recent measurements of Shpil'rain and Nikanorov [86], Sugawara et al. [9], or Schönherr and Hensel [84]. Lange's Handbook [130] includes a note in their table identifying 900 °C as the critical point; this model

deviates substantially from the other correlations at high temperatures. The DIPPR [134] and Yaws [135] correlations appear indistinguishable on the plot, and both have adopted a critical point of 1735 K and 160.8 MPa. Our correlation agrees very well with these correlations up to about 1500 K, where the differences are probably due to the critical point adopted in the correlations. Also, the correlation of Schmutzler (as presented in Götzlaff [13]) adopts a different critical point from the selection here; it uses T_c = 1751 K and p_c = 167.3 MPa. We note that the tabulated values in the book by Hensel and Warren [7] appear to have been generated from the Schmutzler [13] correlation.

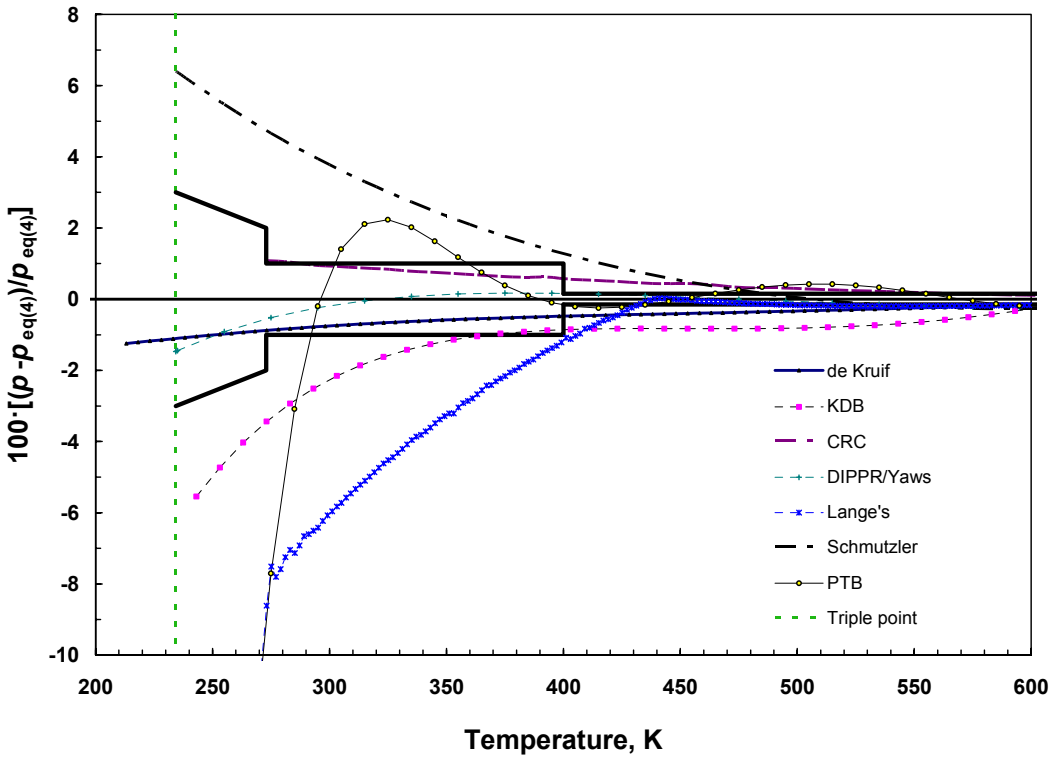


Figure 5a. Comparison of the new correlation, eq (4), with previous compilations and correlations in the low temperature region up to 600 K. The uncertainty band for eq (4) is indicated by a heavy black solid line.

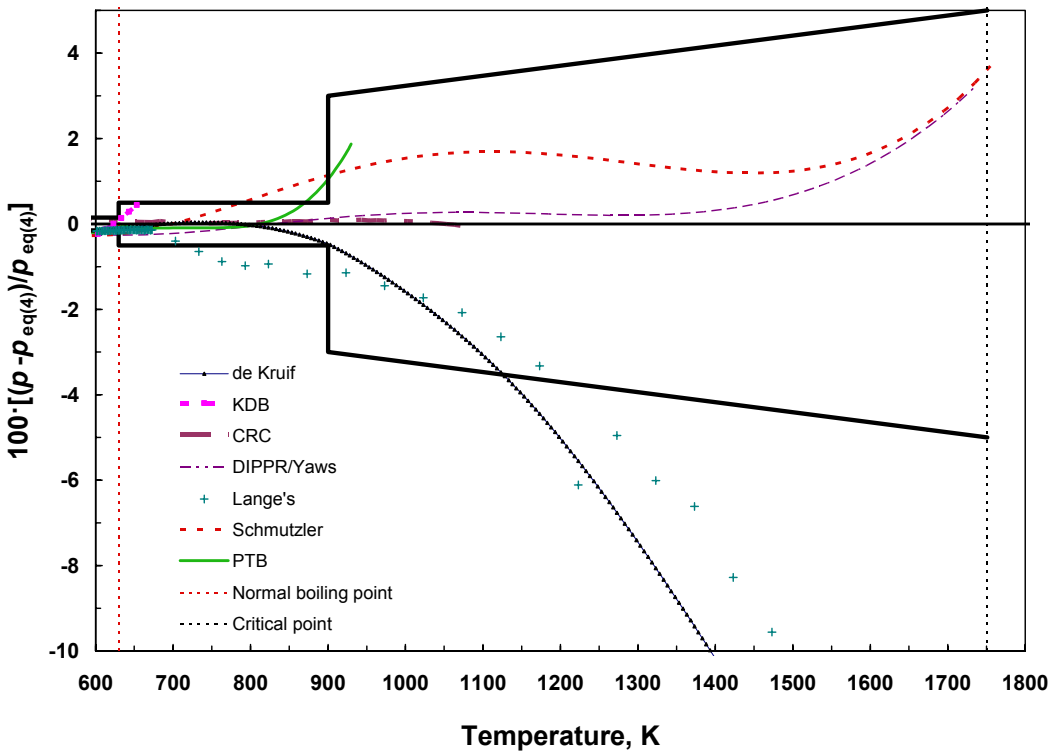


Figure 5b. Comparison of the new correlation, eq (4), with previous compilations and correlations in the high temperature region from 600 K to the critical temperature. The uncertainty band for eq (4) is indicated by a heavy black solid line.

6. Detailed Comparisons for the Temperature Range 0 °C to 60 °C

The temperature range from 0 °C to 60 °C is of particular interest for this project. Unfortunately, in this region there are very few vapor pressure data of high accuracy. Our approach, as detailed above, was to identify the data sets of highest quality and supplement the vapor pressure data with low-temperature heat capacity data to improve the behavior of the correlation at low temperatures and to ensure thermodynamic consistency. The data of Ernsberger and Pitman [54] are the only direct vapor pressure measurements of low uncertainty (1 %) available in this region, and were the only low-temperature vapor pressure data used in the regression. Figure 6a shows the deviations of all data with estimated uncertainties of 3 % or less in this temperature range, while Figure 6b shows comparisons with all sets with estimated uncertainties of 6 % or less. The data

of both Busey and Giauque [44] and Douglas, Ball and Ginnings [51] were not direct measurements but rather were values obtained from their analysis of heat capacity data. Our correlation does not agree with these sets to within their estimated uncertainties; neither do the sets agree with each other to within these uncertainties. The single data point of Scott [85] at 293 K, determined with a quartz fiber manometer with an estimated uncertainty of 2 %, is represented by our correlation within this margin. The measurements of Volmer and Kirchoff [91] have a slightly higher (3 %) estimated uncertainty and are represented well by the correlation.

Figure 7 compares correlations in the literature with eq (4) for the temperature range 273 K to 333 K (0 °C to 60 °C). There are four correlations that agree with eq (4) to within our estimated uncertainty of 1 %: those by de Kruif [20, 21], DIPPR [134], Yaws [135], and Mukhachev et al. [16]. Yaws [135] does not state the uncertainty of his equation; however the DIPPR [134] equation reports an estimated uncertainty of less than 3 %, and the two correlations are almost indistinguishable from one another. The DIPPR correlation was developed by fitting vapor pressure data, with a primary data set consisting of 54 experimental points from Ambrose and Sprake [18] for temperatures from 426 K to 771 K, nine smoothed points from the correlation of Stull [11] for 399 K to 596 K, and 81 points from the tables in Vargaftik [136] for temperatures 273 K to 1073 K [137]. The correlation of de Kruif [20, 21] was developed by use of the method of Clark

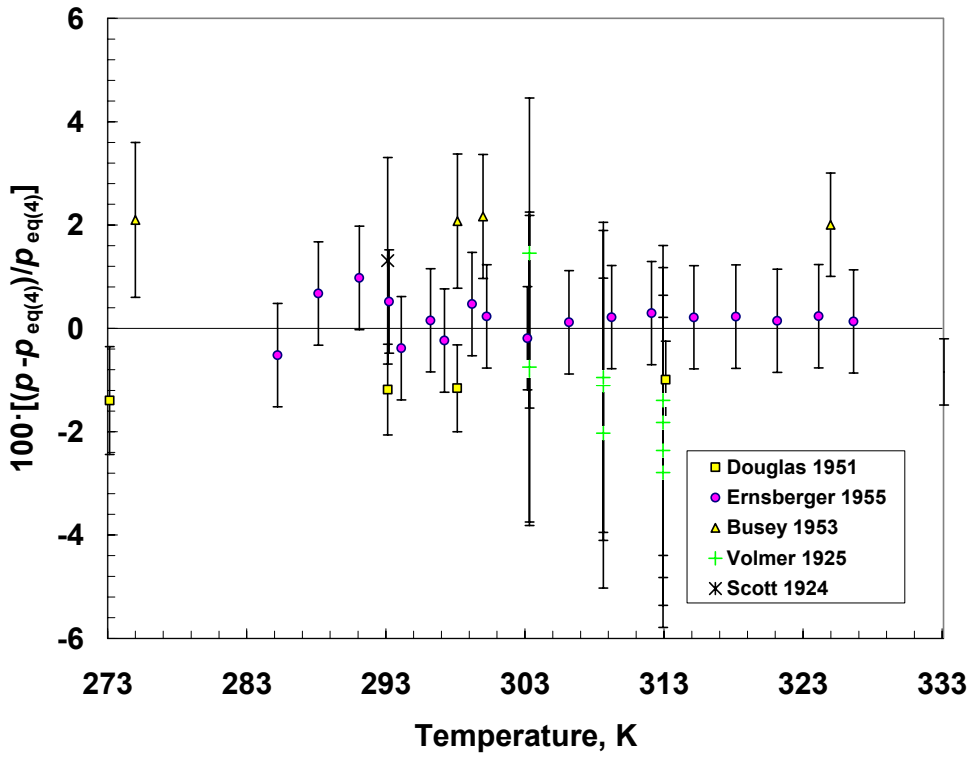


Figure 6a. Comparison of the new correlation, eq (4), in the temperature range 273 K to 333 K, with experimental data with estimated uncertainties of 3 % or less.

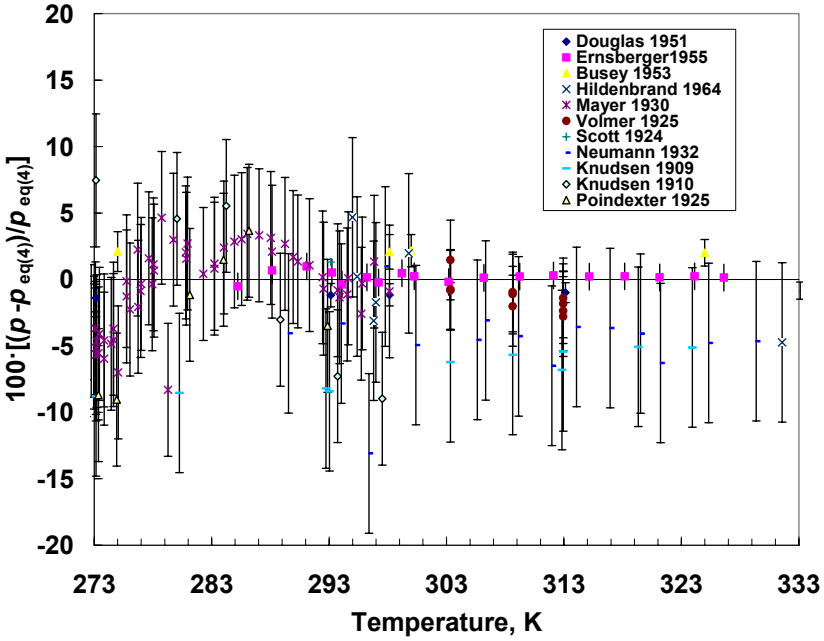


Figure 6b. Comparison of the new correlation, eq (4), in the temperature range 273 K to 333 K, with experimental data with estimated uncertainties of 6 % or less.

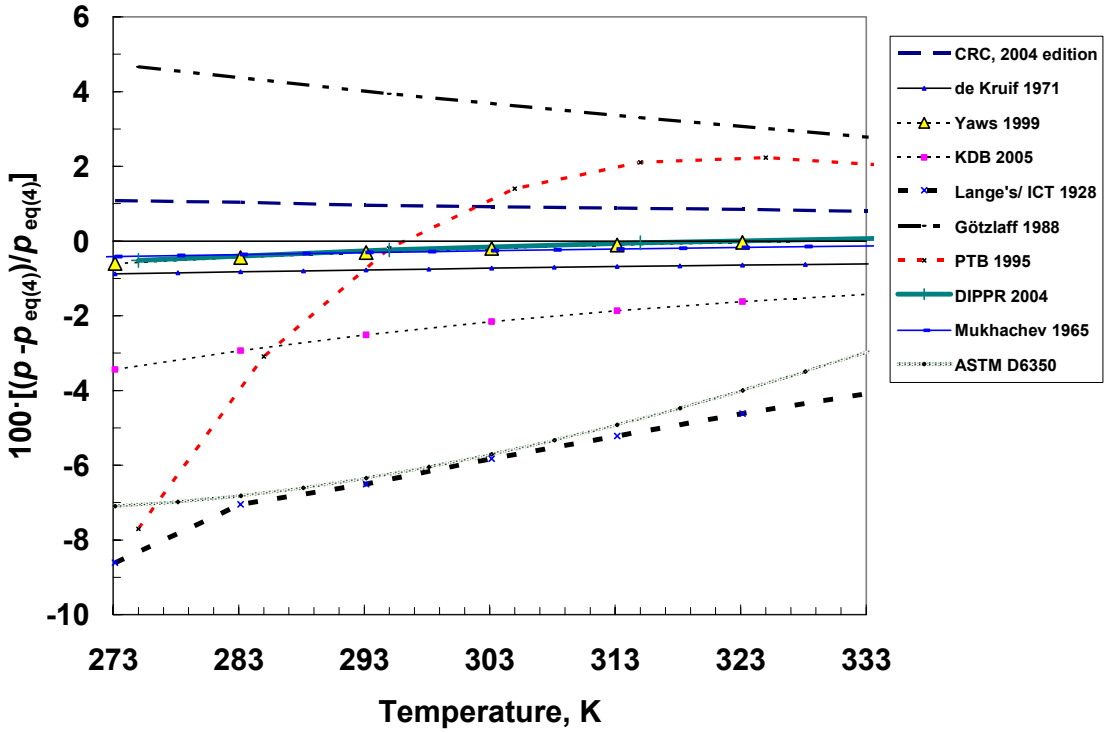


Figure 7. Comparison of the new correlation, eq (4), in the temperature range 273 K to 333 K, with correlations from the literature.

and Glew [138] that, in addition to vapor pressure data, used supplementary data such as heat capacities, Gibbs free energies of vaporization and enthalpies of vaporization to develop the correlation. The curve from the CRC Handbook, 85th Edition is based on that of Vargaftik et al. [8], which itself is based upon Vukalovich and Fokin [4]. The Vukalovich and Fokin [4] source lists the data used in the development of the equation, and apparently they were unaware of the data of Ernsberger and Pitman [54]. As mentioned earlier, Ernsberger and Pitman [54] give an estimated uncertainty of 1 % for their measurements, and they seem to be the most reliable vapor pressure measurements in the 0 °C to 60 °C range. The Mukhachev et al. [16] correlation was developed from caloric data such as heat of vaporization and heat capacities along with the normal boiling point of mercury. The KDB correlation [133] is presented only as a set of

coefficients with a range of applicability, and we do not know the data used in its development; it is consistently lower than our correlation. The PTB curve [22], with a reported maximum uncertainty of 4 %, is very different in shape from all the others investigated. This analysis did not incorporate caloric data, and the experimental data in the 0 °C to 60 °C range that were used in the regression were those of Poindexter [77] and Neumann and Völker [74]. The equation recommended in the ASTM Standard D6350 [139] is presented in terms of a concentration in nanograms per milliliter. We converted the expression to vapor pressure by applying the ideal gas law and using a relative molar mass [129] of 200.59 and gas constant [121] R = 8.314472 J/(mol·K). It agrees well with the values from Lange's Handbook [130]. The curve from Lange's Handbook [130] deviates the most from our correlation, approaching 10 % at 273 K, and gives vapor pressures that are lower than all the other correlations. The curve in Lange's Handbook [130] is based upon the 1928 International Critical Tables (ICT) [131] and was developed with only the limited data and computational methods available at that time.

Since it has been used extensively in handbooks and in industrial standards, further discussion of the 1928 International Critical Tables is warranted. A total of 28 references are given for the 1928 International Critical Tables, with the most recent dated 1926. In addition, some of these references are not original data but rather analysis of literature data [17, 140-143], and only 8 of the references [53, 66, 67, 72, 76, 77, 85, 90] contain data in the range 273 K to 333 K. Details are not given concerning how the data were weighted or the uncertainties of the numbers presented, and it is difficult to know the exact procedure used to obtain the values in the table. However, it was not uncommon, prior to the widespread use of computers, to employ graphical methods. For example, Stull [11] in 1947 states, "the analytical method...was based on semilogarithmic charts measuring 30 × 42 inches (where 1 mm. = 1° C) and colored map tacks representing the plotted points over which a taut thread was stretched." Comparisons with the data cited in the International Critical Tables (Figure 8) indicate that the values of the 1928 International Critical Tables (ICT) [131] in the range 0 °C to 60 °C are in closest agreement with the 1909 data of Knudsen [66]. Figure 8 shows the percent deviations from eq (4) for all of the data cited in the 1928 ICT, the ICT values [131], and the data of Ernsberger and Pitman [54]. The 1955 data of Ernsberger and Pitman [54]

were not available to the authors of the ICT Table; however, it is the primary data source we used in the low temperature region. In addition, Ernsberger and Pitman [54] noted that although the ICT tables are given to four significant figures, the uncertainty is probably 5 to 10 % due to the uncertainties in the measurements upon which the ICT table for mercury is based. Further discussion on the Knudsen [66] data follows since it appears that the ICT tables agree most closely with this particular data set.

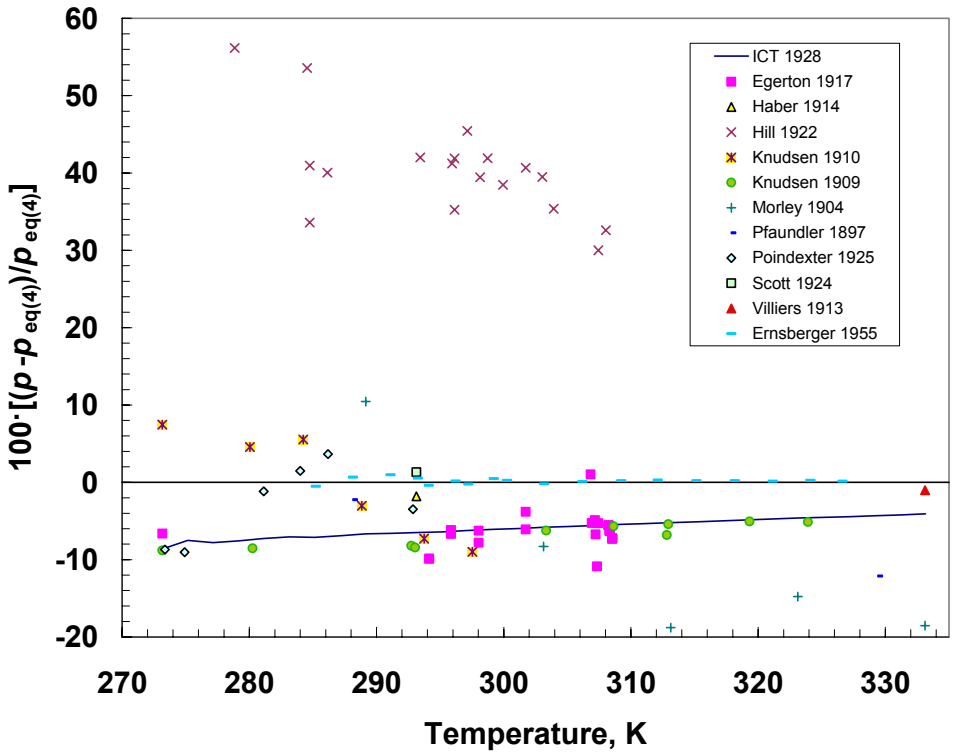


Figure 8. Comparison of the new correlation, eq (4), in the temperature range 273 K to 333 K, with data cited in the references for the 1928 International Critical Tables (ICT) [131], the values in the 1928 ICT, and the data of Ernsberger and Pitman [54].

The vapor pressure data of Knudsen [66] were obtained in 1909 using an effusion method. In fact, it was the very first measurement of this type, and the method is now often called “the Knudsen effusion method” or “the Knudsen method.” Several variants of this method have been developed and have been in continuous use from 1909 until the present day. Cater [144] discussed the state of the art in of the effusion method in 1978; as recently as 2006, Zaitsau et al. [145] used the Knudsen method to measure the vapor

pressure of ε-caprolactam. The basic method developed by Knudsen involves the flow of vapor from a space where it is in equilibrium with a solid or a liquid at a known temperature into a high vacuum through a fine hole or tube. With a known orifice size and geometry, one can measure the flow rate and calculate the vapor pressure with equations based on kinetic theory. The measurements that Knudsen made in 1909 were done very carefully. One measurement at 0 °C took 13 days to complete—his method of detection was to condense the effusing mercury vapor and measure its volume at room temperature in a capillary tube located below the condenser. However, even today, with state of the art equipment, estimated uncertainties for mass-loss Knudsen effusion methods are about 5 % [146, 147] for pressures on the order of 10^{-1} Pa to 1 Pa. EPA guidelines [148] give an estimated repeatability of 10 % to 30 % for mass-loss effusion methods for the pressure range 10^{-3} Pa to 1 Pa. Measurements at such low pressures are difficult; some factors that can contribute to the uncertainty are temperature measurement and control, determination of the weight-loss, and knowledge of the orifice geometry. For finite orifice lengths, the geometry must be well known in order to compute the Clausing factor, which corrects for the fact that some molecules may strike the orifice wall and be returned to the cell [144]. In contrast, there is a 1 % uncertainty associated with the direct manometric method of Ernsberger and Pittman [54].

One can also demonstrate that the ICT Tables, apparently based on the data of Knudsen [66], are thermodynamically inconsistent with low temperature heat capacity data. Figure 9a shows comparisons of the calculated and experimental values of heat capacity, and Figure 9b compares the experimental and calculated values for the vapor pressure using the present vapor pressure equation eq (4). Sakonidou et al. [6] reviewed the availability of heat capacity data for mercury and identified three major sets of heat capacity data for the low temperature (below 60 °C) region: Busey and Giauque [44] (0.1 % uncertainty), Douglas et al. [51] (1 % uncertainty) and Amitin et al. [123](1 % uncertainty). These sets of heat capacity data are represented to within their experimental uncertainties, as are the vapor pressure data of Ernberger and Pitman [54] (1 % uncertainty). The Knudsen data [66] are represented to within 5 % to 10 %, a level consistent with the effusion technique, with the highest deviations at the lowest temperatures. Therefore, our equation represents all of these data sets to within their

uncertainties, and the heat capacity data are thermodynamically consistent with the vapor pressure data. However, if one refits the vapor pressure equation, but instead of using the data of Ernsberger and Pitman [54] as primary data, one instead uses the data of Knudsen [66], and adjusts the weights so that the resulting vapor pressure equation represents the Knudsen data to within 2 %, it is no longer possible to represent the heat capacities to within their experimental uncertainty, as shown in Figure 10a. This indicates that the Knudsen data, at a 2 % uncertainty level, are thermodynamically inconsistent with the heat capacity measurements. Therefore the 1928 ICT Tables, that represent the Knudsen data to better than 2 %, are thermodynamically inconsistent with the heat capacity measurements of Busey and Giauque [44], Douglas et al. [51], and Amitin et al. [123]. To summarize, the effusion data of Knudsen [66] can be assigned a temperature-dependent uncertainty of 5 % to 10 %; any attempt to ascribe a smaller uncertainty to this data set would be inconsistent with the more recent data of Ernsberger and Pitman [54], Busey and Giauque [44], Douglas et al. [51], and Amitin et al. [123].

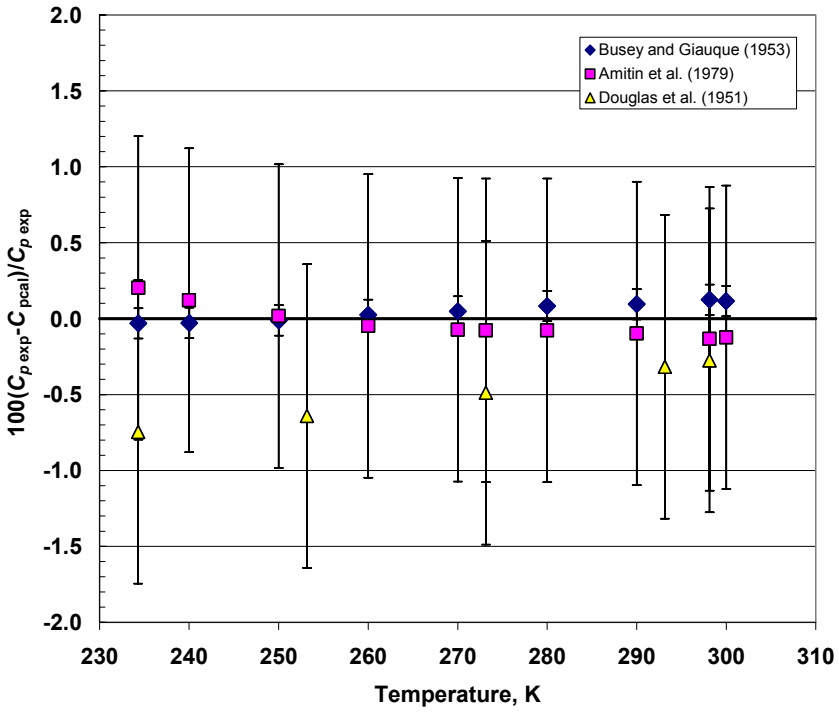


Figure 9a. Comparison of heat capacities calculated with the present correlation, eq (4) and eq (2), with experimental heat capacity data.

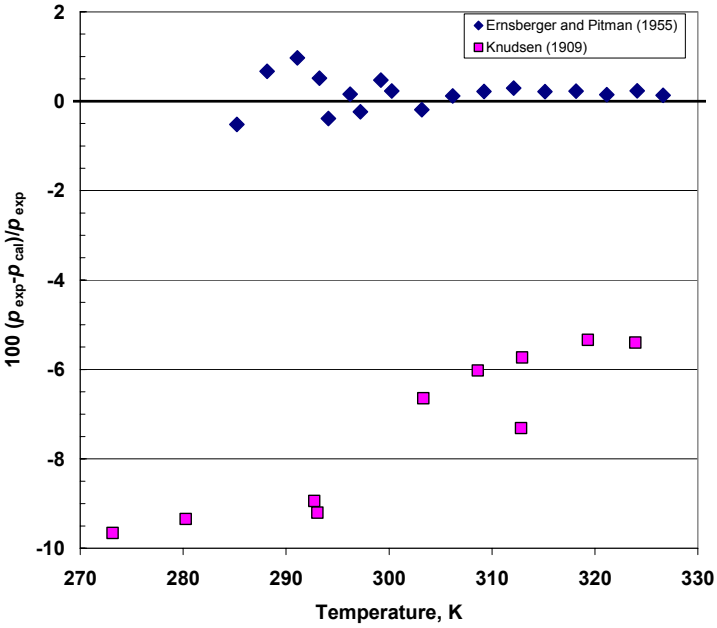


Figure 9b. Comparison of vapor pressures calculated with the present correlation, eq (4), with experimental vapor pressure data.

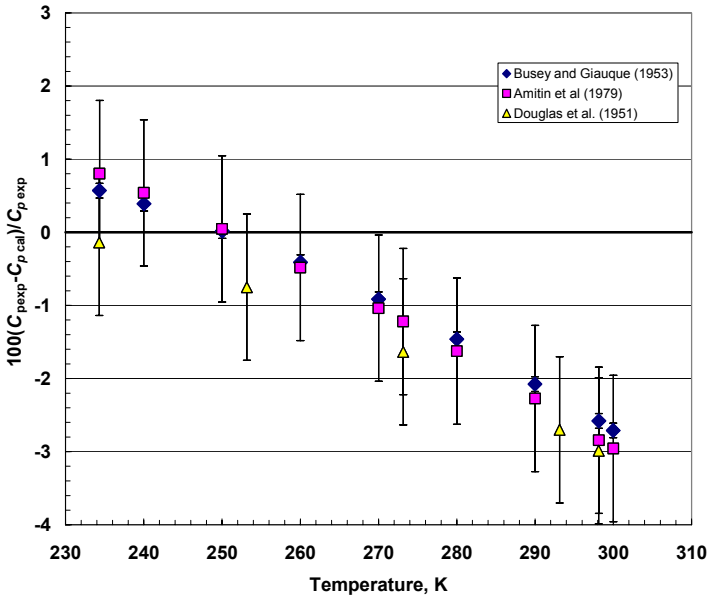


Figure 10a. Comparison of heat capacities calculated with eq (1) and eq (2), subject to the constraint that the vapor pressure data of Knudsen be represented to within 2 %, with experimental heat capacity data.

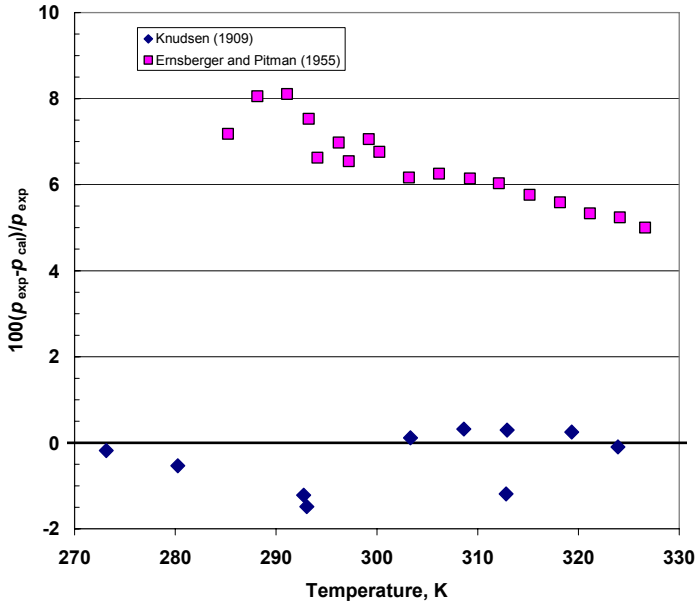


Figure 10b. Comparison of vapor pressures calculated with eq (1) and eq (2), subject to the constraint that the vapor pressure data of Knudsen be represented to within 2 %, with experimental vapor pressure data.

7. Conclusions

We developed a new correlation for the vapor pressure of mercury that is valid from the triple point [30], 234.3156 K to the critical point [105], 1764 K using a Wagner-type equation. We have determined the uncertainties to be associated with the equation through our comparisons with the primary experimental data and consideration of the uncertainties of these data as discussed above. The estimated uncertainty at a coverage factor of two varies from 3 % near the triple point to 1 % for temperatures from 273 K to 400 K; 0.15 % for the intermediate temperature region from 400 K to the normal boiling point at 629.77 K; for temperatures above the normal boiling point but below about 900 K it is 0.5 %; and for temperatures between 900 K and the critical point we estimate the uncertainty is about 5 %. The new correlation gives a normal boiling point (101.325 kPa) of 629.77 K.

This project was supported in part by the Western Research Institute, and was prepared with the support of the U.S. Department of Energy, under Award No. DE-FC26-98FT40323. However, any opinions, findings, conclusions, or recommendations expressed herein are those of NIST and do not necessarily reflect the views of the DOE. We thank the staff of the Department of Commerce Boulder Laboratories Library for their dedication and cheerful assistance in obtaining the historic literature necessary for this project, and Dr. Harro Bauer (Physikalisch-Technische Bundesanstalt, Braunschweig, Germany) for providing us with a copy of ref. [22]. We thank NIST PREP student Justin Chichester for assistance with the preparation of this manuscript and NIST Guest Researcher Ilmudtin Abdulagatov for assistance with Russian literature. We also acknowledge helpful discussions with our NIST colleagues Mark McLinden, Allan Harvey, and Gerald Mitchell, and with Dr. John Schabron of the Western Research Institute.

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Appendix A. Detailed Listing of Experimental Data for the Vapor Pressure of Mercury

All temperatures have been converted to ITS-90. Data are arranged alphabetically by first author.

Data from Ambrose and Sprake [18]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
379.934	0.046	681.168	237.992	635.136	111.503
400.340	0.139	685.426	253.933	636.491	114.202
417.095	0.293	702.724	327.808	621.615	87.311
426.204	0.424	711.623	371.975	623.249	89.986
432.281	0.538	726.554	456.609	624.850	92.662
439.292	0.706	739.690	543.039	626.410	95.342
441.719	0.774	749.788	617.883	627.956	98.055
447.681	0.964	771.124	802.526	629.467	100.770
451.381	1.101	481.650	3.023	630.924	103.440
454.121	1.213	488.128	3.689	632.343	106.101
456.320	1.309	494.925	4.522	633.750	108.792
462.634	1.627	500.619	5.339	635.136	111.504
469.182	2.024	506.657	6.342	636.492	114.202
474.565	2.414	513.690	7.708	621.622	87.323
479.040	2.784	520.258	9.205	623.266	90.010
485.150	3.369	526.171	10.753	624.853	92.671
491.856	4.128	533.782	13.074	626.418	95.353
497.530	4.882	541.589	15.879	627.958	98.060
533.454	12.965	546.934	18.080	629.466	100.764
541.345	15.780	555.219	21.998	630.924	103.441
549.473	19.193	562.504	26.013	632.343	106.101
554.721	21.742	572.032	32.173	633.750	108.794
562.759	26.162	579.202	37.584	635.130	111.489
572.231	32.313	587.994	45.215	636.492	114.202
579.977	38.203	596.471	53.760	621.625	87.331
589.082	46.244	605.005	63.675	623.267	90.014
597.320	54.686	612.930	74.144	624.855	92.672
605.650	64.484	621.863	87.728	626.413	95.348
611.991	72.866	628.996	99.929	627.951	98.043
621.147	86.564	629.758	101.311	629.465	100.764
627.808	97.795	630.156	102.037	630.923	103.440
628.883	99.711	621.619	87.316	632.342	106.098
629.949	101.643	623.258	90.004	633.747	108.789
638.367	118.032	624.850	92.667	635.135	111.501
629.365	100.600	626.421	95.363	636.488	114.195
639.863	121.141	627.960	98.061		
645.494	133.558	629.464	100.768		
654.707	155.987	630.923	103.440		
663.194	179.295	632.340	106.099		
671.779	205.659	633.748	108.792		

Data from Beattie, Blaisdell, and Kaminsky [28]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
629.7632	101.325	635.6476	112.492	631.1879	103.940
629.7648	101.325	635.4589	112.121	632.6278	106.646
629.7666	101.325	634.1509	109.565	633.9426	109.160
629.7676	101.325	632.8014	106.976	634.9149	111.047
629.7632	101.325	631.4044	104.344	633.6486	108.587
629.7663	101.325	629.9633	101.688	632.2578	105.943
622.9608	89.5232	628.4226	98.8973	630.6593	102.963
624.5575	92.1883	626.8527	96.1257	629.1704	100.244
626.0545	94.7394	625.3936	93.6046	627.6159	97.4703
627.6855	97.5908	623.2927	90.0733	626.0489	94.7299
629.0765	100.075	623.0797	89.7188	624.5171	92.1186
630.5802	102.819	624.9884	92.9141	622.9920	89.5730
632.0069	105.472	626.7624	95.9670		
633.4298	108.168	628.2268	98.5483		
634.7126	110.655	629.7562	101.312		

Data from Bernhardt [41]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
693	343.2	1074	9807	1619	125500
693	313.8	1114	12750	1663	146100
743	568.8	1174	14910	1674	155900
753	519.8	1199	16670	1685	164400
794	980.7	1368	46090	1685	173600
794	1079	1488	88260	1685	181400
844	1618	1553	104000	1706	198100
854	1471	1608	105400		
944	3334	1614	111800		
1004	6865	1619	118700		

Data from Bessel-Hagen [42]

T, K	p, kPa
273	0.00197
293	0.00268

Data from Burlingame [43]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
377.2	$4.560 \cdot 10^{-2}$	408.9	$2.045 \cdot 10^{-1}$	473.6	2.318
377.1	$4.613 \cdot 10^{-2}$	443.2	$8.126 \cdot 10^{-1}$	473.6	2.321
377.1	$4.546 \cdot 10^{-2}$	443.2	$8.069 \cdot 10^{-1}$	343.6	$7.186 \cdot 10^{-3}$
377.0	$4.613 \cdot 10^{-2}$	443.2	$8.083 \cdot 10^{-1}$	343.6	$6.999 \cdot 10^{-3}$
377.0	$4.560 \cdot 10^{-2}$	443.2	$8.162 \cdot 10^{-1}$	343.7	$7.146 \cdot 10^{-3}$
377.1	$4.506 \cdot 10^{-2}$	443.2	$8.194 \cdot 10^{-1}$	343.6	$7.146 \cdot 10^{-3}$
377.2	$4.426 \cdot 10^{-2}$	473.5	2.297	343.7	$7.039 \cdot 10^{-3}$
377.1	$4.613 \cdot 10^{-2}$	473.5	2.306	343.7	$7.093 \cdot 10^{-3}$
408.9	$2.074 \cdot 10^{-1}$	473.6	2.314		
408.9	$2.070 \cdot 10^{-1}$	473.6	2.353		
408.8	$2.122 \cdot 10^{-1}$	473.6	2.333		
408.8	$2.134 \cdot 10^{-1}$	473.6	2.337		
408.9	$1.971 \cdot 10^{-1}$	473.6	2.341		
408.8	$2.038 \cdot 10^{-1}$	473.6	2.316		
408.9	$2.042 \cdot 10^{-1}$	473.6	2.322		

Data from Busey and Giauque [44]

T, K	p, kPa	T, K	p, kPa
234.32	$3.07 \cdot 10^{-7}$	500.01	5.256
250.02	$2.24 \cdot 10^{-6}$	525.02	$1.044 \cdot 10^{1}$
275.00	$3.31 \cdot 10^{-5}$	550.03	$1.947 \cdot 10^{1}$
298.15	$2.67 \cdot 10^{-4}$	575.03	$3.429 \cdot 10^{1}$
299.98	$3.11 \cdot 10^{-4}$	600.04	$5.757 \cdot 10^{1}$
324.98	$2.05 \cdot 10^{-3}$	625.04	$9.274 \cdot 10^{1}$
349.97	$1.03 \cdot 10^{-2}$	629.92	$1.013 \cdot 10^{2}$
374.97	$4.144 \cdot 10^{-2}$	650.03	$1.437 \cdot 10^{2}$
399.98	$1.397 \cdot 10^{-1}$	675.03	$2.156 \cdot 10^{2}$
424.99	$4.077 \cdot 10^{-1}$	700.02	$3.140 \cdot 10^{2}$
449.99	1.054	725.01	$4.452 \cdot 10^{2}$
475.00	2.458	750.00	$6.165 \cdot 10^{2}$

Data from Cailletet , Colardeau, and Rivìere [45]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
673	$2.13 \cdot 10^{2}$	924	$3.45 \cdot 10^{3}$	1154	$1.64 \cdot 10^{4}$
723	$4.31 \cdot 10^{2}$	974	$5.07 \cdot 10^{3}$		
774	$8.11 \cdot 10^{2}$	1024	$7.30 \cdot 10^{3}$		
824	$1.40 \cdot 10^{3}$	1074	$1.03 \cdot 10^{4}$		
874	$2.26 \cdot 10^{3}$	1124	$1.393 \cdot 10^{4}$		

Data from Callendar and Griffiths [46]

T,K	p, kPa
629.79	101.325
629.95	101.325

Data from Carlson, Gilles and Thorn [48]

T, K	p, kPa	T, K	p, kPa
301.38	$3.5064 \cdot 10^{-4}$	406.28	$2.718 \cdot 10^{-1}$
324.08	$1.947 \cdot 10^{-3}$	448.29	1.652
336.97	$4.626 \cdot 10^{-3}$	499.21	8.371
348.27	$9.306 \cdot 10^{-3}$	548.83	$3.145 \cdot 10^{1}$
372.17	$4.226 \cdot 10^{-2}$		

Data from Dauphinee [49, 50]

T, K	p, kPa	T, K	p, kPa
454.88	1.2407	345.08	$7.44739 \cdot 10^{-3}$
444.55	$8.6353 \cdot 10^{-1}$	353.45	$1.26496 \cdot 10^{-2}$
382.91	$6.0968 \cdot 10^{-2}$	361.31	$2.00317 \cdot 10^{-2}$
396.41	$1.1984 \cdot 10^{-1}$	405.29	$1.7885 \cdot 10^{-1}$
405.17	$1.6799 \cdot 10^{-1}$	483.27	3.2547
413.90	$2.5794 \cdot 10^{-1}$	513.53	7.7820
421.97	$3.6650 \cdot 10^{-1}$	332.82	$3.4624 \cdot 10^{-3}$
433.36	$5.8142 \cdot 10^{-1}$	314.02	$9.2179 \cdot 10^{-4}$
323.72	$1.78119 \cdot 10^{-3}$	305.00	$4.1703 \cdot 10^{-4}$

Data from Douglas, Ball, and Ginnings [51]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
234.30	$2.921 \cdot 10^{-7}$	413.13	$2.4663 \cdot 10^{-1}$	$6.1319 \cdot 10^{2}$	$7.4557 \cdot 10^{1}$
253.17	$3.114 \cdot 10^{-6}$	433.14	$5.5722 \cdot 10^{-1}$	$6.2977 \cdot 10^{2}$	$1.0133 \cdot 10^{2}$
273.15	$2.661 \cdot 10^{-5}$	453.15	1.1697	$6.3318 \cdot 10^{2}$	$1.0772 \cdot 10^{2}$
293.14	$1.691 \cdot 10^{-4}$	473.15	2.3029	$6.5318 \cdot 10^{2}$	$1.52074 \cdot 10^{2}$
298.14	$2.580 \cdot 10^{-4}$	493.16	4.2859	$6.7318 \cdot 10^{2}$	$2.10201 \cdot 10^{2}$
313.13	$8.453 \cdot 10^{-4}$	513.17	7.5902	$6.9317 \cdot 10^{2}$	$2.85011 \cdot 10^{2}$
333.12	$3.4728 \cdot 10^{-3}$	533.17	$1.2863 \cdot 10^{1}$	$7.1317 \cdot 10^{2}$	$3.79714 \cdot 10^{2}$
353.12	$1.2126 \cdot 10^{-2}$	553.18	$2.0963 \cdot 10^{1}$	$7.3316 \cdot 10^{2}$	$4.9780 \cdot 10^{2}$
373.12	$3.6944 \cdot 10^{-2}$	573.18	$3.2986 \cdot 10^{1}$	$7.5315 \cdot 10^{2}$	$6.4300 \cdot 10^{2}$
393.13	$1.0028 \cdot 10^{-1}$	593.19	$5.0299 \cdot 10^{1}$	$7.7315 \cdot 10^{2}$	$8.1932 \cdot 10^{2}$

Data from Egerton [53]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
306.83	$5.320 \cdot 10^{-4}$	298.04	$2.426 \cdot 10^{-4}$	308.53	$5.573 \cdot 10^{-4}$
306.93	$5.026 \cdot 10^{-4}$	295.86	$2.023 \cdot 10^{-4}$	294.14	$1.680 \cdot 10^{-4}$
307.43	$5.226 \cdot 10^{-4}$	295.86	$2.023 \cdot 10^{-4}$	307.23	$5.066 \cdot 10^{-4}$
307.18	$5.146 \cdot 10^{-4}$	308.23	$5.546 \cdot 10^{-4}$	308.33	$5.546 \cdot 10^{-4}$
288.64	$8.613 \cdot 10^{-5}$	308.53	$5.573 \cdot 10^{-4}$	308.33	$5.546 \cdot 10^{-4}$
307.33	$4.880 \cdot 10^{-4}$	308.53	$5.573 \cdot 10^{-4}$	308.33	$5.546 \cdot 10^{-4}$
273.15	$2.520 \cdot 10^{-5}$	294.14	$1.680 \cdot 10^{-4}$	308.33	$5.546 \cdot 10^{-4}$
301.73	$3.373 \cdot 10^{-4}$	295.86	$2.013 \cdot 10^{-4}$	308.53	$5.573 \cdot 10^{-4}$
298.04	$2.386 \cdot 10^{-4}$	295.86	$2.013 \cdot 10^{-4}$		
301.73	$3.293 \cdot 10^{-4}$	308.23	$5.546 \cdot 10^{-4}$		

Data from Ernsberger and Pitman [54]

T, K	p, kPa	T, K	p, kPa
285.22	$8.453 \cdot 10^{-5}$	315.15	$9.949 \cdot 10^{-4}$
288.15	$1.113 \cdot 10^{-4}$	318.17	$1.242 \cdot 10^{-3}$
291.10	$1.448 \cdot 10^{-4}$	321.15	$1.539 \cdot 10^{-3}$
294.11	$1.852 \cdot 10^{-4}$	324.12	$1.900 \cdot 10^{-3}$
297.22	$2.412 \cdot 10^{-4}$	326.63	$2.260 \cdot 10^{-3}$
300.25	$3.116 \cdot 10^{-4}$	293.24	$1.735 \cdot 10^{-4}$
303.18	$3.934 \cdot 10^{-4}$	296.22	$2.226 \cdot 10^{-4}$
306.17	$5.005 \cdot 10^{-4}$	299.20	$2.865 \cdot 10^{-4}$
309.23	$6.358 \cdot 10^{-4}$		
312.11	$7.929 \cdot 10^{-4}$		

Data from Gebhardt [57]

T, K	p, kPa	T, K	p, kPa
403.13	$1.47 \cdot 10^{-1}$	453.15	1.23
413.13	$2.40 \cdot 10^{-1}$	463.15	1.73
423.13	$3.73 \cdot 10^{-1}$	473.15	2.36
433.14	$5.73 \cdot 10^{-1}$	483.16	3.20
443.14	$8.40 \cdot 10^{-1}$		

Data from Haber and Kerschbaum [37]

T, K	p, kPa
293.142	$1.680 \cdot 10^{-4}$

Data from Hagen [58]

T, K	p, kPa
273.15	$2.00 \cdot 10^{-3}$
323.13	$5.60 \cdot 10^{-3}$
373.12	$2.80 \cdot 10^{-2}$
423.13	$2.56 \cdot 10^{-1}$
473.15	2.126

Data from Hertz [35]

T, K	p, kPa	T, K	p, kPa
362.52	$2.13 \cdot 10^{-2}$	457.85	1.472
390.13	$9.47 \cdot 10^{-2}$	463.55	1.719
427.34	$4.65 \cdot 10^{-1}$	476.15	2.713
438.94	$7.36 \cdot 10^{-1}$	480.06	3.010
450.54	1.09		

Data from Heycock and Lamplough [60]

T, K	p, kPa
628.89	101.325

Data from Hildenbrand, Hall, Ju and Potter [61]

T, K	p, kPa	T, K	p, kPa
295.4	$2.08 \cdot 10^{-4}$	295.0	$2.10 \cdot 10^{-4}$
296.8	$2.26 \cdot 10^{-4}$	299.8	$3.05 \cdot 10^{-4}$
297.0	$2.33 \cdot 10^{-4}$	331.6	$3.01 \cdot 10^{-3}$

Data from Hill [62]

T, K	p, kPa	T, K	p, kPa
272.45	$4.40 \cdot 10^{-5}$	297.14	$3.49 \cdot 10^{-4}$
278.85	$7.33 \cdot 10^{-5}$	298.14	$3.64 \cdot 10^{-4}$
284.54	$1.23 \cdot 10^{-4}$	298.73	$3.89 \cdot 10^{-4}$
284.74	$1.15 \cdot 10^{-4}$	299.93	$4.19 \cdot 10^{-4}$
284.74	$1.09 \cdot 10^{-4}$	301.73	$4.93 \cdot 10^{-4}$
286.14	$1.29 \cdot 10^{-4}$	303.03	$5.43 \cdot 10^{-4}$
293.44	$2.49 \cdot 10^{-4}$	303.93	$5.67 \cdot 10^{-4}$
295.94	$3.07 \cdot 10^{-4}$	307.43	$7.17 \cdot 10^{-4}$
296.14	$2.99 \cdot 10^{-4}$	308.03	$7.67 \cdot 10^{-4}$
296.14	$3.13 \cdot 10^{-4}$		

Data from Jenkins [64]

T, K	p, kPa	T, K	p, kPa
479.16	2.27	600.19	$5.56 \cdot 10^{1}$
493.66	3.80	604.19	$6.07 \cdot 10^{1}$
511.17	6.47	615.19	$7.76 \cdot 10^{1}$
520.67	8.27	623.19	$8.85 \cdot 10^{1}$
526.17	$1.01 \cdot 10^{1}$	631.19	$1.03 \cdot 10^{2}$
532.67	$1.21 \cdot 10^{1}$	637.71	$1.16 \cdot 10^{2}$
549.68	$1.85 \cdot 10^{1}$	643.74	$1.27 \cdot 10^{2}$
561.68	$2.513 \cdot 10^{1}$	653.77	$1.508 \cdot 10^{2}$
576.68	$3.56 \cdot 10^{1}$	664.31	$1.789 \cdot 10^{2}$
581.68	$3.79 \cdot 10^{1}$	670.83	$1.987 \cdot 10^{2}$
589.69	$4.47 \cdot 10^{1}$		

Data from Kahlbaum [65]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
392.53	$1.16 \cdot 10^{-1}$	427.34	$4.64 \cdot 10^{-1}$	459.05	1.527
397.83	$1.83 \cdot 10^{-1}$	432.24	$5.64 \cdot 10^{-1}$	464.25	1.797
399.03	$1.68 \cdot 10^{-1}$	434.24	$5.85 \cdot 10^{-1}$	466.25	1.867
404.23	$2.81 \cdot 10^{-1}$	435.74	$6.17 \cdot 10^{-1}$	469.85	2.212
407.23	$2.21 \cdot 10^{-1}$	438.24	$6.83 \cdot 10^{-1}$	472.55	2.332
408.13	$2.43 \cdot 10^{-1}$	441.84	$8.03 \cdot 10^{-1}$	474.95	2.549
411.73	$2.93 \cdot 10^{-1}$	446.24	1.01	477.95	2.805
413.33	$3.53 \cdot 10^{-1}$	448.34	1.04	479.06	2.864
414.83	$3.13 \cdot 10^{-1}$	449.44	1.05	482.06	3.097
417.43	$2.67 \cdot 10^{-1}$	449.94	1.09	483.76	3.357
418.33	$3.81 \cdot 10^{-1}$	450.04	1.05	487.46	3.836
420.23	$3.69 \cdot 10^{-1}$	452.75	1.17	489.76	4.117
421.33	$3.96 \cdot 10^{-1}$	454.05	1.26	492.96	4.573
422.13	$4.25 \cdot 10^{-1}$	454.75	1.25		
424.64	$4.37 \cdot 10^{-1}$	456.15	1.409		

Data from Knudsen [67]

T, K	p, kPa	T, K	p, kPa
263.16	$1.10 \cdot 10^{-5}$	288.84	$1.14 \cdot 10^{-4}$
273.15	$2.90 \cdot 10^{-5}$	293.74	$1.67 \cdot 10^{-4}$
280.05	$5.50 \cdot 10^{-5}$	297.54	$2.26 \cdot 10^{-4}$
284.24	$8.20 \cdot 10^{-5}$		

Data from Knudsen [66]

T, K	p, kPa	T, K	p, kPa
273.15	$2.461 \cdot 10^{-5}$	308.63	$5.713 \cdot 10^{-4}$
280.25	$4.902 \cdot 10^{-5}$	312.93	$7.954 \cdot 10^{-4}$
292.74	$1.517 \cdot 10^{-4}$	319.33	$1.280 \cdot 10^{-3}$
293.04	$1.553 \cdot 10^{-4}$	312.83	$7.778 \cdot 10^{-4}$
303.33	$3.741 \cdot 10^{-4}$	323.93	$1.775 \cdot 10^{-3}$

Data from Kordes and Raaz [68]

T, K	p, kPa
630.19	101.325
632.19	101.325

Data from Mayer [69]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
262.16	$6.27\cdot10^{-6}$	272.45	$2.45\cdot10^{-5}$	295.84	$2.15\cdot10^{-4}$
263.26	$7.73\cdot10^{-6}$	272.75	$2.49\cdot10^{-5}$	296.84	$2.37\cdot10^{-4}$
264.66	$9.20\cdot10^{-6}$	273.45	$2.67\cdot10^{-5}$	298.14	$2.59\cdot10^{-4}$
265.66	$1.04\cdot10^{-5}$	273.85	$2.76\cdot10^{-5}$	261.46	$6.13\cdot10^{-6}$
266.65	$1.15\cdot10^{-5}$	274.65	$2.99\cdot10^{-5}$	262.16	$6.80\cdot10^{-6}$
267.65	$1.29\cdot10^{-5}$	275.75	$3.48\cdot10^{-5}$	262.76	$7.47\cdot10^{-6}$
268.55	$1.48\cdot10^{-5}$	276.70	$3.91\cdot10^{-5}$	263.16	$8.13\cdot10^{-6}$
268.95	$1.53\cdot10^{-5}$	277.65	$4.25\cdot10^{-5}$	264.46	$9.47\cdot10^{-6}$
269.60	$1.65\cdot10^{-5}$	278.75	$4.87\cdot10^{-5}$	264.86	$1.01\cdot10^{-5}$
270.45	$1.85\cdot10^{-5}$	279.75	$5.27\cdot10^{-5}$	265.46	$1.11\cdot10^{-5}$
271.40	$2.09\cdot10^{-5}$	280.94	$5.88\cdot10^{-5}$	265.66	$1.12\cdot10^{-5}$
272.25	$2.32\cdot10^{-5}$	282.29	$6.52\cdot10^{-5}$	266.56	$1.29\cdot10^{-5}$
273.10	$2.59\cdot10^{-5}$	283.24	$7.15\cdot10^{-5}$	267.55	$1.51\cdot10^{-5}$
273.20	$2.59\cdot10^{-5}$	284.04	$7.81\cdot10^{-5}$	267.75	$1.47\cdot10^{-5}$
274.65	$3.01\cdot10^{-5}$	284.94	$8.52\cdot10^{-5}$	269.75	$1.81\cdot10^{-5}$
276.05	$3.51\cdot10^{-5}$	286.04	$9.47\cdot10^{-5}$	272.35	$2.36\cdot10^{-5}$
277.00	$3.92\cdot10^{-5}$	287.04	$1.03\cdot10^{-4}$	272.95	$2.52\cdot10^{-5}$
278.10	$4.40\cdot10^{-5}$	288.14	$1.13\cdot10^{-4}$	273.15	$2.55\cdot10^{-5}$
278.05	$4.40\cdot10^{-5}$	289.24	$1.25\cdot10^{-4}$	273.15	$2.56\cdot10^{-5}$
279.30	$4.49\cdot10^{-5}$	290.34	$1.36\cdot10^{-4}$	273.35	$2.60\cdot10^{-5}$
280.84	$5.76\cdot10^{-5}$	291.34	$1.48\cdot10^{-4}$	273.85	$2.72\cdot10^{-5}$
280.79	$5.76\cdot10^{-5}$	292.44	$1.61\cdot10^{-4}$	274.45	$2.92\cdot10^{-5}$
283.24	$7.17\cdot10^{-5}$	293.74	$1.79\cdot10^{-4}$	275.05	$3.03\cdot10^{-5}$
285.54	$9.01\cdot10^{-5}$	294.54	$1.91\cdot10^{-4}$	275.75	$3.44\cdot10^{-5}$
288.04	$1.13\cdot10^{-4}$	295.74	$2.08\cdot10^{-4}$	276.75	$3.76\cdot10^{-5}$
289.94	$1.32\cdot10^{-4}$	292.54	$1.61\cdot10^{-4}$	276.95	$3.88\cdot10^{-5}$
272.00	$2.31\cdot10^{-5}$	293.89	$1.80\cdot10^{-4}$	277.95	$4.29\cdot10^{-5}$

Data from McLeod [70]

T, K	p, kPa
293.14	0.000765

Data from Menzies [40, 94]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
394.92	$1.1052 \cdot 10^{-1}$	602.72	$6.0942 \cdot 10^{1}$	645.54	$1.3366 \cdot 10^{2}$
423.10	$3.7357 \cdot 10^{-1}$	607.01	$6.6396 \cdot 10^{1}$	651.46	$1.4781 \cdot 10^{2}$
464.58	1.7359	611.05	$7.1667 \cdot 10^{1}$	656.74	$1.6140 \cdot 10^{2}$
526.92	$1.0943 \cdot 10^{1}$	615.66	$7.8228 \cdot 10^{1}$	659.45	$1.6873 \cdot 10^{2}$
533.29	$1.2911 \cdot 10^{1}$	619.97	$8.4660 \cdot 10^{1}$	662.35	$1.7680 \cdot 10^{2}$
537.10	$1.4201 \cdot 10^{1}$	620.57	$8.5622 \cdot 10^{1}$	666.82	$1.9012 \cdot 10^{2}$
540.92	$1.5604 \cdot 10^{1}$	624.95	$9.3023 \cdot 10^{1}$	677.05	$2.2335 \cdot 10^{2}$
544.75	$1.7141 \cdot 10^{1}$	625.06	$9.3022 \cdot 10^{1}$	679.94	$2.3255 \cdot 10^{2}$
548.61	$1.8805 \cdot 10^{1}$	627.66	$9.7609 \cdot 10^{1}$	683.43	$2.4629 \cdot 10^{2}$
556.53	$2.2641 \cdot 10^{1}$	628.79	$9.9700 \cdot 10^{1}$	689.93	$2.7159 \cdot 10^{2}$
565.97	$2.8103 \cdot 10^{1}$	630.13	$1.0205 \cdot 10^{2}$	692.87	$2.8342 \cdot 10^{2}$
571.23	$3.1592 \cdot 10^{1}$	630.54	$1.0256 \cdot 10^{2}$	699.29	$3.1121 \cdot 10^{2}$
577.63	$3.6429 \cdot 10^{1}$	633.86	$1.0892 \cdot 10^{2}$	706.78	$3.4653 \cdot 10^{2}$
583.62	$4.1294 \cdot 10^{1}$	635.24	$1.1151 \cdot 10^{2}$	707.47	$3.4988 \cdot 10^{2}$
587.20	$4.4652 \cdot 10^{1}$	638.43	$1.1809 \cdot 10^{2}$		
599.51	$5.7186 \cdot 10^{1}$	641.34	$1.2434 \cdot 10^{2}$		

Data from Millar [71]

T, K	p, kPa	T, K	p, kPa
468.30	1.960	575.33	$3.449 \cdot 10^{1}$
518.02	8.319	613.04	$7.475 \cdot 10^{1}$
571.93	$3.264 \cdot 10^{1}$	613.94	$7.605 \cdot 10^{1}$

Data from Morley [72]

T, K	p, kPa	T, K	p, kPa
289.14	$1.33 \cdot 10^{-4}$	323.13	$1.51 \cdot 10^{-3}$
303.13	$3.60 \cdot 10^{-4}$	333.12	$2.85 \cdot 10^{-3}$
313.13	$6.93 \cdot 10^{-4}$	343.12	$5.39 \cdot 10^{-3}$

Data from Murgulescu and Topor [73]

T, K	p, kPa	T, K	p, kPa
465.65	1.91	532.17	$1.27 \cdot 10^{1}$
476.15	2.57	546.58	$1.808 \cdot 10^{1}$
485.16	3.36	549.58	$1.933 \cdot 10^{1}$
494.16	4.44	559.18	$2.438 \cdot 10^{1}$
507.57	6.63		

Data from Neumann and Völker [74]

T, K	*p,* kPa	*T*, K	*p*, kPa
343.82	$6.881 \cdot 10^{-3}$	311.98	$7.32 \cdot 10^{-4}$
338.82	$5.005 \cdot 10^{-3}$	309.13	$6.03 \cdot 10^{-4}$
335.62	$3.956 \cdot 10^{-3}$	306.33	$4.91 \cdot 10^{-4}$
334.02	$3.557 \cdot 10^{-3}$	305.63	$4.57 \cdot 10^{-4}$
329.38	$2.597 \cdot 10^{-3}$	300.38	$2.99 \cdot 10^{-4}$
325.33	$1.964 \cdot 10^{-3}$	297.79	$2.56 \cdot 10^{-4}$
321.23	$1.448 \cdot 10^{-3}$	296.39	$1.96 \cdot 10^{-4}$
319.53	$1.31 \cdot 10^{-3}$	294.04	$1.79 \cdot 10^{-4}$
316.93	$1.09 \cdot 10^{-3}$	289.54	$1.20 \cdot 10^{-4}$
314.08	$8.84 \cdot 10^{-4}$		

Data from Pedder and Barratt [75]

T, K	*p*, kPa
556.68	22.49
557.18	22.61
573.18	33.13

Data from Pfaundler [76]

T, K	*p*, kPa
288.14	$1.080 \cdot 10^{-4}$
329.43	$2.401 \cdot 10^{-3}$
371.92	$3.507 \cdot 10^{-2}$

Data from Poindexter [77]

T, K	*p*, kPa	*T*, K	*p*, kPa
235.34	$1.84 \cdot 10^{-7}$	267.44	$1.34 \cdot 10^{-5}$
240.44	$3.63 \cdot 10^{-7}$	269.17	$1.65 \cdot 10^{-5}$
242.20	$4.95 \cdot 10^{-7}$	273.36	$2.52 \cdot 10^{-5}$
245.03	$7.60 \cdot 10^{-7}$	274.91	$2.92 \cdot 10^{-5}$
250.43	$1.56 \cdot 10^{-6}$	281.13	$5.76 \cdot 10^{-5}$
252.60	$2.34 \cdot 10^{-6}$	284.00	$7.71 \cdot 10^{-5}$
255.94	$3.28 \cdot 10^{-6}$	286.18	$9.61 \cdot 10^{-5}$
261.16	$6.95 \cdot 10^{-6}$	292.87	$1.61 \cdot 10^{-4}$
262.35	$7.86 \cdot 10^{-6}$		
193.58*	$4.00 \cdot 10^{-10}$	216.31*	$6.91 \cdot 10^{-9}$
203.25*	$8.00 \cdot 10^{-10}$	223.30*	$3.16 \cdot 10^{-8}$
206.30*	$5.33 \cdot 10^{-9}$	229.75*	$9.75 \cdot 10^{-8}$
209.47*	$1.69 \cdot 10^{-9}$	230.38*	$1.00 \cdot 10^{-7}$
215.43*	$6.47 \cdot 10^{-9}$	231.39*	$1.14 \cdot 10^{-7}$

* Point below triple point, not included in analysis.

Data from Ramsay and Young [36]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
495.31	4.59	630.67	$1.0244 \cdot 10^{2}$	631.87	$1.0106 \cdot 10^{2}$
543.98	$1.6579 \cdot 10^{1}$	630.67	$1.0223 \cdot 10^{2}$	720.46	$3.8622 \cdot 10^{2}$
553.38	$2.0952 \cdot 10^{1}$	632.46	$1.0240 \cdot 10^{2}$	721.46	$3.8723 \cdot 10^{2}$
631.65	$1.0260 \cdot 10^{2}$	632.46	$1.0214 \cdot 10^{2}$		
631.65	$1.0269 \cdot 10^{2}$	631.87	$1.0181 \cdot 10^{2}$		

Data from Regnault [33]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
296.71	$9.07 \cdot 10^{-3}$	473.65	2.934	627.79	$1.0109 \cdot 10^{2}$
311.14	$1.31 \cdot 10^{-2}$	631.66	$1.022 \cdot 10^{2}$	686.34	$2.0393 \cdot 10^{2}$
373.72	$7.40 \cdot 10^{-2}$	524.25	9.88	701.77	$3.5813 \cdot 10^{2}$
298.52	$4.53 \cdot 10^{-3}$	525.77	$1.04 \cdot 10^{1}$	717.51	$4.2405 \cdot 10^{2}$
322.28	$1.16 \cdot 10^{-2}$	528.62	$1.13 \cdot 10^{1}$	749.24	$6.1513 \cdot 10^{2}$
345.86	$2.44 \cdot 10^{-2}$	570.39	$3.1781 \cdot 10^{1}$	785.22	$9.7548 \cdot 10^{2}$
373.23	$5.43 \cdot 10^{-2}$	587.25	$4.6103 \cdot 10^{1}$	782.08	$9.3193 \cdot 10^{2}$
373.72	$7.47 \cdot 10^{-2}$	604.79	$6.4836 \cdot 10^{1}$	773.42	$7.9543 \cdot 10^{2}$
419.43	$4.61 \cdot 10^{-1}$	618.08	$8.3313 \cdot 10^{1}$	627.79	$1.0109 \cdot 10^{2}$
451.04	1.429	628.02	$1.0157 \cdot 10^{2}$		

Data from Rodebush and Dixon [79]

T, K	p, kPa	T, K	p, kPa
443.54	$8.39 \cdot 10^{-1}$	462.75	1.644
451.24	1.11	470.35	2.104
453.25	1.17	475.95	2.520
457.05	1.351		

Data from Roeder and Morawietz [80]

T, K	p, kPa	T, K	p, kPa
413.13	$2.433 \cdot 10^{-1}$	523.17	9.930
433.14	$5.466 \cdot 10^{-1}$	563.18	$2.646 \cdot 10^{1}$
453.15	1.187	613.19	$7.363 \cdot 10^{1}$
483.16	3.160		

Data from Ruff and Bergdahl [81]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
478.15	1.6	573.18	$2.91 \cdot 10^{1}$	625.19	$1.01 \cdot 10^{2}$
508.17	4.3	583.18	$4.23 \cdot 10^{1}$	630.19	$1.01 \cdot 10^{2}$
513.17	4.7	597.19	$5.04 \cdot 10^{1}$		
533.17	$1.2 \cdot 10^{1}$	615.19	$6.87 \cdot 10^{1}$		
543.18	$1.3 \cdot 10^{1}$	628.19	$1.00 \cdot 10^{2}$		

Data from Schmahl, Barthel and Kaloff [82]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
446.64	$9.3 \cdot 10^{-1}$	519.17	8.92	617.69	$8.121 \cdot 10^{1}$
449.64	1.0	529.17	$1.15 \cdot 10^{1}$	621.19	$8.765 \cdot 10^{1}$
478.15	2.72	531.67	$1.25 \cdot 10^{1}$	628.19	$9.806 \cdot 10^{1}$
479.66	2.84	540.68	$1.540 \cdot 10^{1}$	629.69	$1.010 \cdot 10^{2}$
482.16	3.04	549.68	$1.919 \cdot 10^{1}$	637.18	$1.148 \cdot 10^{2}$
487.66	3.60	551.68	$2.034 \cdot 10^{1}$	639.68	$1.211 \cdot 10^{2}$
492.66	4.23	562.68	$2.604 \cdot 10^{1}$	412.43	$2.37 \cdot 10^{-1}$
493.66	4.36	572.68	$3.260 \cdot 10^{1}$	415.33	$2.69 \cdot 10^{-1}$
498.66	4.99	574.18	$3.350 \cdot 10^{1}$	420.43	$3.32 \cdot 10^{-1}$
498.66	5.07	579.18	$3.746 \cdot 10^{1}$	425.64	$4.15 \cdot 10^{-1}$
499.16	5.13	582.68	$4.041 \cdot 10^{1}$	430.64	$5.03 \cdot 10^{-1}$
504.16	5.84	596.19	$5.313 \cdot 10^{1}$	435.54	$6.03 \cdot 10^{-1}$
507.17	6.36	606.19	$6.467 \cdot 10^{1}$	438.64	$6.81 \cdot 10^{-1}$
509.67	6.97	609.19	$6.819 \cdot 10^{1}$		
510.67	6.97	616.69	$7.923 \cdot 10^{1}$		

Data from Schneider and Schupp [83]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
539.68	$1.484 \cdot 10^{1}$	500.16	5.31	550.18	$1.943 \cdot 10^{1}$
519.17	8.00	491.16	4.00	552.18	$2.038 \cdot 10^{1}$
519.17	7.93	484.16	2.95	553.18	$2.024 \cdot 10^{1}$
518.17	7.88	523.17	$1.01 \cdot 10^{1}$	554.18	$2.190 \cdot 10^{1}$
521.67	9.05	501.16	5.37	545.18	$1.727 \cdot 10^{1}$
519.17	8.81	502.16	5.21	563.18	$2.686 \cdot 10^{1}$
519.67	9.67	502.16	5.07	550.18	$1.933 \cdot 10^{1}$
575.18	$3.468 \cdot 10^{1}$	551.18	$1.993 \cdot 10^{1}$		

Data from Schönherr and Hensel [84]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
1051.44	90	1581.99	991	1716.40	1490
1186.24	200	1632.52	1155	1726.05	1535
1322.14	382	1665.97	1275	1735.51	1575
1424.66	571	1686.68	1345		
1510.37	782	1704.76	1430		

Data from Scott [85]

T, K	p, kPa
293.14	$1.73 \cdot 10^{-4}$

Data from Shpil'rain and Nikanorov [86]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
554.11	$2.152 \cdot 10^{1}$	635.61	$1.123 \cdot 10^{2}$	786.77	$9.6252 \cdot 10^{2}$
560.61	$2.505 \cdot 10^{1}$	639.81	$1.210 \cdot 10^{2}$	796.86	$1.0798 \cdot 10^{3}$
567.11	$2.893 \cdot 10^{1}$	642.11	$1.257 \cdot 10^{2}$	814.46	$1.3057 \cdot 10^{3}$
578.91	$3.740 \cdot 10^{1}$	643.81	$1.293 \cdot 10^{2}$	836.25	$1.63551 \cdot 10^{3}$
600.61	$5.854 \cdot 10^{1}$	664.30	$1.8254 \cdot 10^{2}$	803.66	$1.16117 \cdot 10^{3}$
604.11	$6.261 \cdot 10^{1}$	707.29	$3.4921 \cdot 10^{2}$	815.46	$1.31973 \cdot 10^{3}$
621.11	$8.635 \cdot 10^{1}$	742.78	$5.6147 \cdot 10^{2}$	822.45	$1.42302 \cdot 10^{3}$
622.21	$8.811 \cdot 10^{1}$	755.98	$6.6372 \cdot 10^{2}$	831.85	$1.56996 \cdot 10^{3}$
623.71	$9.038 \cdot 10^{1}$	774.67	$8.3905 \cdot 10^{2}$	845.39	$1.79551 \cdot 10^{3}$
626.81	$9.547 \cdot 10^{1}$	648.01	$1.3862 \cdot 10^{2}$	847.24	$1.82505 \cdot 10^{3}$
629.41	$1.002 \cdot 10^{2}$	677.30	$2.2531 \cdot 10^{2}$	854.54	$1.96728 \cdot 10^{3}$
635.21	$1.117 \cdot 10^{2}$	681.50	$2.3779 \cdot 10^{2}$	856.44	$1.99968 \cdot 10^{3}$
643.31	$1.279 \cdot 10^{2}$	694.70	$2.9070 \cdot 10^{2}$	866.64	$2.21186 \cdot 10^{3}$
619.71	$8.419 \cdot 10^{1}$	724.09	$4.4107 \cdot 10^{2}$	880.43	$2.51478 \cdot 10^{3}$
628.11	$9.815 \cdot 10^{1}$	732.39	$4.9111 \cdot 10^{2}$	882.13	$2.55352 \cdot 10^{3}$
628.31	$9.889 \cdot 10^{1}$	752.68	$6.3837 \cdot 10^{2}$	883.23	$2.57295 \cdot 10^{3}$
630.91	$1.034 \cdot 10^{2}$	774.57	$8.3449 \cdot 10^{2}$		

Data from Spedding and Dye [87]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
533.825	$1.306 \cdot 10^{1}$	573.610	$3.3293 \cdot 10^{1}$	613.886	$7.5568 \cdot 10^{1}$
549.811	$1.9337 \cdot 10^{1}$	586.013	$4.3390 \cdot 10^{1}$	620.254	$8.5144 \cdot 10^{1}$
558.948	$2.3954 \cdot 10^{1}$	594.741	$5.1918 \cdot 10^{1}$	630.244	$1.0222 \cdot 10^{2}$
564.721	$2.7351 \cdot 10^{1}$	597.253	$5.4588 \cdot 10^{1}$		
565.743	$2.7964 \cdot 10^{1}$	604.288	$6.2792 \cdot 10^{1}$		

Data from Stock and Zimmermann [88]

T, K	p, kPa
283.14	$7.33 \cdot 10^{-5}$
273.15	$2.39 \cdot 10^{-5}$
253.17	$4.40 \cdot 10^{-6}$
213.19*	$6.53 \cdot 10^{-7}$

* Point below triple point, not included in analysis.

Data from Sugawara, Sato, and Minamiyama [9]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
601.67	$6.0389 \cdot 10^{1}$	735.22	$5.2093 \cdot 10^{2}$	873.15	$2.3650 \cdot 10^{3}$
630.83	$1.0258 \cdot 10^{2}$	768.75	$7.9022 \cdot 10^{2}$	892.71	$2.8647 \cdot 10^{3}$
664.10	$1.8162 \cdot 10^{2}$	795.55	$1.0710 \cdot 10^{3}$	918.61	$3.5883 \cdot 10^{3}$
683.99	$2.4860 \cdot 10^{2}$	824.15	$1.4651 \cdot 10^{3}$	929.62	$3.8828 \cdot 10^{3}$
705.03	$3.3804 \cdot 10^{2}$	853.24	$1.9858 \cdot 10^{3}$		

Data from van der Plaats [89]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
273.15	$6.27 \cdot 10^{-4}$	287.14	$1.32 \cdot 10^{-3}$	289.14	$1.53 \cdot 10^{-3}$
283.14	$1.07 \cdot 10^{-3}$	280.15	$9.47 \cdot 10^{-4}$	286.14	$1.33 \cdot 10^{-3}$
287.14	$1.33 \cdot 10^{-3}$	283.14	$1.06 \cdot 10^{-3}$	286.14	$1.25 \cdot 10^{-3}$
285.14	$1.35 \cdot 10^{-3}$	283.14	$1.12 \cdot 10^{-3}$	287.14	$1.35 \cdot 10^{-3}$
291.14	$1.77 \cdot 10^{-3}$	273.15	$6.40 \cdot 10^{-4}$		
273.15	$5.60 \cdot 10^{-4}$	292.14	$1.72 \cdot 10^{-3}$		
277.15	$7.73 \cdot 10^{-4}$	273.15	$5.87 \cdot 10^{-4}$		
282.14	$9.73 \cdot 10^{-4}$	284.14	$1.11 \cdot 10^{-3}$		
283.14	$1.03 \cdot 10^{-3}$	354.12	$1.49 \cdot 10^{-2}$		
273.15	$6.87 \cdot 10^{-4}$	358.12	$1.66 \cdot 10^{-2}$		
293.14	$1.77 \cdot 10^{-3}$	285.14	$7.73 \cdot 10^{-4}$		

Data from Villiers [90]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
333.12	$3.47 \cdot 10^{-3}$	373.12	$4.00 \cdot 10^{-2}$	365.12	$2.55 \cdot 10^{-2}$
341.12	$5.73 \cdot 10^{-3}$	333.12	$3.67 \cdot 10^{-3}$	373.12	$4.01 \cdot 10^{-2}$
349.12	$1.01 \cdot 10^{-2}$	341.12	$5.87 \cdot 10^{-3}$		
357.12	$1.64 \cdot 10^{-2}$	349.12	$1.03 \cdot 10^{-2}$		
365.12	$2.57 \cdot 10^{-2}$	357.12	$1.64 \cdot 10^{-2}$		

Data from Volmer and Kirchhoff [91]

T, K	p, kPa	T, K	p, kPa
312.93	$8.293 \cdot 10^{-4}$	308.63	$5.934 \cdot 10^{-4}$
312.93	$8.175 \cdot 10^{-4}$	308.63	$5.990 \cdot 10^{-4}$
303.33	$4.048 \cdot 10^{-4}$	308.63	$6.000 \cdot 10^{-4}$
303.33	$3.957 \cdot 10^{-4}$	312.93	$8.257 \cdot 10^{-4}$
303.33	$3.960 \cdot 10^{-4}$	312.93	$8.211 \cdot 10^{-4}$

Data from von Halban [92]

T, K	p, kPa
255.16	$3.76 \cdot 10^{-6}$
219.79*	$3.31 \cdot 10^{-8}$

* Point below triple point, not included in analysis.

Data from Young [93]

T, K	p, kPa	T, K	p, kPa	T, K	p, kPa
456.95	1.33	495.31	4.59	629.95	$1.013 \cdot 10^{2}$
456.85	1.31	510.12	6.91	716.60	$3.862 \cdot 10^{2}$
510.07	6.913	543.48	$1.658 \cdot 10^{1}$	717.60	$3.872 \cdot 10^{2}$
456.90	1.32	553.38	$2.095 \cdot 10^{1}$		

Appendix B. Detailed Listing of Supplemental Experimental Data for the Heat Capacity of Mercury

All temperatures have been converted to ITS-90. Data are arranged alphabetically by first author.

Smoothed data from Amitin, Lebedeva and Paukov [123]

T, K	C_p, J/(mol·K)	T, K	C_p, J/(mol·K)
234.3375	28.543	289.9958	27.987
240.0066	28.473	298.1437	27.911
250.0049	28.359	299.9932	27.899
260.0029	28.255		
270.0007	28.162		
273.1500	28.134		
279.9984	28.076		

Smoothed data from Busey and Giauque [44]

T, K	C_p, J/(mol·K)	T, K	C_p, J/(mol·K)
234.3206	28.476	349.9729*	27.606
240.0264	28.430	399.9785	27.359
250.0185	28.351	449.9942	27.204
260.0103	28.275	500.0132	27.129
270.0024	28.196	550.0289	27.117
279.9953	28.121	600.0361	27.146
289.9893	28.041	650.0326	27.217
298.1452	27.983	700.0199	27.338
299.9843	27.966	750.0049	27.514

* Note: Maximum temperature of their measurements was 330 K; values at higher temperatures are based on measurements in the literature.

Smoothed data from Douglas et al. [51]

T, K	C_p, J/(mol·K)	T, K	C_p, J/(mol·K)
234.3006	28.275	513.1679	27.158
253.166	28.147	533.1743	27.141
273.15	28.019	553.1796	27.132
293.1376	27.900	573.1835	27.130
298.1352	27.872	593.1858	27.137
313.1293	27.790	613.1863	27.150
333.1245	27.688	629.7653	27.167
353.1229	27.595	633.185	27.171
373.1238	27.511	653.182	27.198
393.127	27.435	673.1776	27.232
413.1319	27.368	693.172	27.274
433.1382	27.309	713.1658	27.321
453.1454	27.259	733.1596	27.374
473.153	27.217	753.1541	27.433
493.1607	27.183	773.1501	27.499