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# A PRELIMINARY COLLATION OF THE THERMODYNAMIC AND TRANSPORT PROPERTIES OF POTASSIUM

H. W. Hoffman and B. Cox

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H. W. Hoffman and B. Cox

This work was performed for the National Aeronautics and Space Administration under AEC Interagency Agreement 40-98-66, NASA Order W-12,353.

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
Operated by
UNION CARBIDE CORPORATION
for the
U. S. ATOMIC ENERGY COMMISSION

# FOREWORD

This report summarizes an analytical comparison of cesium and potassium as working fluids for Rankine cycle space power plants. The work was conducted by the Oak Ridge National Laboratory for NASA under AEC Interagency Agreement 40-98-66, NASA Order W-12,353 under the technical management of A. P. Fraas of the Oak Ridge National Laboratory. Project management for NASA was performed by S. V. Manson of NASA Headquarters.

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## CONVERSION FACTORS

### DENSITY EQUIVALENTS

| $g/cm^3$ | $lb_m/in.^3$ | $lb_m/ft^3$ |
|---|---|---|
| 1 | 0.03613 | 62.43 |
| 27.68 | 1 | 1728 |
| 0.01602 | 0.0005787 | 1 |

### ENERGY EQUIVALENTS

| Joules = $10^7$ ergs | Calorie | Btu | kw·hr |
|---|---|---|---|
| 1 | 0.2390 | 0.0009484 | $2.778 \times 10^{-7}$ |
| 4.184 | 1 | 0.00397 | $1.162 \times 10^{-6}$ |
| 1054.4 | 252 | 1 | $2.930 \times 10^{-4}$ |
| $3.6 \times 10^6$ | $8.606 \times 10^5$ | 3413 | 1 |

### HEAT CAPACITY-ENTROPY EQUIVALENTS

$$1 \text{ cal/g-mole}\cdot{}^\circ\text{C} = 1 \text{ Btu/lb}_m\cdot\text{mole}\cdot{}^\circ\text{F}$$

$$1 \text{ cal/g}\cdot{}^\circ\text{C} = 1 \text{ Btu/lb}_m\cdot{}^\circ\text{F}$$

### ENTHALPY/MASS EQUIVALENTS

| cal/g | $Btu/lb_m$ | $Joules/kg_m$ |
|---|---|---|
| 1 | 1.8 | 4184 |
| 0.5556 | 1 | 2324.4 |
| $2.390 \times 10^{-4}$ | $4.302 \times 10^{-4}$ | 1 |

PRESSURE EQUIVALENTS

| dynes/cm$^2$ | kg$_f$/m$^2$ | atm | mm of Hg at 0°C (torr) | lb$_f$/in.$^2$ |
|---|---|---|---|---|
| 1 | 0.010197 | $9.869 \times 10^{-7}$ | $7.501 \times 10^{-4}$ | $1.450 \times 10^{-5}$ |
| 98.07 | 1 | $9.678 \times 10^{-5}$ | 0.073556 | $1.422 \times 10^{-3}$ |
| $1.0133 \times 10^{6}$ | 10,323 | 1 | 760 | 14.696 |
| $1.333 \times 10^{3}$ | | 0.001316 | 1 | 0.01934 |
| $6.895 \times 10^{4}$ | | 0.06804 | 51.715 | 1 |

THERMAL CONDUCTIVITY EQUIVALENTS

| cal/sec·cm·°C | watts/cm·°C | Btu/hr·ft·°F | Btu/sec·ft·°F |
|---|---|---|---|
| 1 | 4.184 | 241.92 | 0.06720 |
| 0.2390 | 1 | 57.82 | 0.1606 |
| $4.1336 \times 10^{-3}$ | 0.01729 | 1 | $2.7778 \times 10^{-4}$ |
| 14.88 | 62.26 | 3600 | 1 |

THERMAL DIFFUSIVITY EQUIVALENTS

| cm$^2$/sec | m$^2$/sec | ft$^2$/sec | ft$^2$/hr |
|---|---|---|---|
| 1 | $10^{-4}$ | $1.0764 \times 10^{-3}$ | 3.8747 |
| $10^4$ | 1 | 10.764 | $3.8747 \times 10^4$ |
| 929.02 | 0.092902 | 1 | 3600 |
| 0.25806 | $2.5806 \times 10^{-5}$ | $2.7778 \times 10^{-4}$ | 1 |

VISCOSITY EQUIVALENTS

| centipoise | $lb_m/ft \cdot sec$ | $lb_m/ft \cdot hr$ |
|---|---|---|
| 1 | $6.7197 \times 10^{-4}$ | 2.4191 |
| 1488.2 | 1 | 3600 |
| 0.41338 | $2.7778 \times 10^{-4}$ | 1 |

SURFACE TENSION EQUIVALENTS

| dynes/cm | $kg_f/m$ | $lb_f/ft$ |
|---|---|---|
| 1 | $1.0197 \times 10^{-4}$ | $6.8521 \times 10^{-5}$ |
| 9807 | 1 | 0.6730 |
| $1.4572 \times 10^{4}$ | 1.486 | 1 |

# A PRELIMINARY COLLATION OF THE THERMODYNAMIC AND TRANSPORT PROPERTIES OF POTASSIUM

H. W. Hoffman and B. Cox

## ABSTRACT

This memorandum compiles data on the properties of potassium in the saturated-liquid and saturated- and superheated-vapor states and is intended to provide a convenient and consistent data source for those engaged in the design and evaluation of power systems based on thermodynamic cycles using potassium as the working fluid. Included are (1) the nuclear properties — cross section to thermal neutrons, natural isotopic abundance, radionuclide decay characteristics, and neutron interactions, (2) the thermodynamic properties — physical constants, critical state conditions, sonic velocities, PVT relationships (equation of state, vapor pressure, density, and compressibility), enthalpy, latent heat of vaporization, heat capacity, entropy, and surface tension, and (3) the transport properties — viscosity, thermal conductivity, and electrical resistivity. The data are presented both in tabular form (summarizing available data) and in graphical form (giving the recommended values). A preliminary and limited evaluation of the data is attempted; and while the situation is somewhat better than for the cesium properties (presented in a companion report), there is an indicated need for additional measurements of some properties.

# INTRODUCTION

The thermodynamic, transport, and nuclear properties of saturated liquid and vapor potassium are presented in the sections which follow. The properties of superheated vapor are tabulated in Appendix B. The data are given both as graphs of each specific property over the temperature range 1100 to 2500°R constituting a preliminary recommendation for design calculations and as tabulations of available equations (or data) for each property including temperature range of applicability, reported error, measurement technique, and source and date of the investigation. Each main section is preceded by a brief discussion of the properties within that section and some preliminary evaluation and justification of the recommended data. A minimal amount of detail is included in these comments; for further elaboration, reference should be made to the original sources.

To provide some perspective, a limited comparison of potassium properties with those of the other alkali metals follows:

| Metal | Atomic Weight | $T_M$ (°F) | $T_B$ (°F) | $\rho_\ell$ ($lb_m/ft^3$) | $\rho_v$ ($lb_m/ft^3$) | $\Delta H_{vap}$ (Btu/$lb_m$) | $C_{p,\ell}$ (Btu/$lb_m$·°F) | $k_\ell$ (Btu/hr·ft·°F) |
|---|---|---|---|---|---|---|---|---|
| Li | 6.9 | 357 | 2430 | 27 | 0.004 | 8338 | 0.98 | 43.8 |
| Na | 23.0 | 208 | 1619 | 46 | 0.02 | 1666 | 0.31 | 28.1 |
| K | 39.1 | 146 | 1394 | 42 | 0.03 | 830 | 0.19 | 17.8 |
| Rb | 85.5 | 102 | 1270 | 82 | 0.06 | 348 | 0.09 | 14.5 |
| Cs | 132.9 | 83 | 1236 | 92 | 0.11 | 212 | 0.06 | 9.4 |

The properties shown were evaluated at the boiling temperature and are only approximate. Except for liquid density, a systematic progression with increasing atomic weight is noted for each of the tabulated properties.

Cesim properties were published in a companion report, ORNL-TM-1755, June 1967.

## PHYSICAL CONSTANTS AND NUCLEAR PROPERTIES

Potassium is a soft, silver-white alkali metal. It melts at 145.8°F (63.2°C) and boils,* under atmospheric pressure, at 1393.9°F (756.6°C). The atomic weight is 39.102 based on $C^{12}$ = 12.000. Potassium does not burn in dry air but will oxidize slowly at room temperature to the stable superoxide, $KO_2$. The latter compound is sometimes explosive under as yet incompletely defined circumstances. In moist air, the solid encrusts rapidly with oxide; at higher temperatures, dispersed liquid droplets will burn. Reaction with liquid water is violent, igniting the liberated hydrogen.

Potassium has three naturally occurring isotopes with mass numbers 39, 40, and 41 and abundances as shown in Table 1. The isotope $K^{40}$ is naturally radioactive with the indicated half-life of $1.25 \times 10^9$ yr. The decay scheme of $K^{40}$ shows a 0.89 probability of emission of a 1.32 Mev electron ($\beta^-$) to form $Ca^{40}$ and a 0.11 probability of electron capture followed by a 1.46 Mev $\gamma$ emission to form $Ar^{40}$. The characteristics of the radionuclides of potassium are summarized in the lower portion of Table 1. The multiple energies listed indicate a $\beta^-$ emission to an excited state followed by a $\gamma$ emission to the ground state; the decay scheme details are not shown.

Perhaps of more importance than the radionuclides of potassium are its interactions with neutrons. The reactions of significant interest are as follows:

$$K^{39} \xrightarrow[(n,\ 2n)]{} K^{38} \xrightarrow[\substack{\beta^+(2.7\ \text{Mev}) \\ \gamma\ (2.2\ \text{Mev})}]{7.7\ \text{min}} Ar^{38}$$

*Based on vapor pressure determination of Ewing et al. (see Table 5 and Fig. 2).

$$K^{39} \xrightarrow[(n,\ p)]{} Ar^{39} \xrightarrow[\beta^{-}(0.57\ \text{Mev})]{270\ \text{yr}} K^{39}$$

$$K^{41} \xrightarrow[(n,p)]{} Cl^{38} \xrightarrow[\substack{\beta^{-}(1.20,\ 2.50\ \text{Mev}) \\ \gamma\ (1.29\ \text{Mev})}]{1.83\ \text{hr}} K^{41}$$

$$K^{41} \xrightarrow[(n,\ \alpha)]{} Cl^{38} \xrightarrow[\substack{\beta^{-}(4.81,\ 2.77,\ 1.1\ \text{Mev}) \\ \gamma\ (1.60,\ 2.15\ \text{Mev})}]{37.3\ \text{min}} Ar^{38}$$

A summary of the physical constants and nuclear properties of potassium is given in Table 1.

Table 1. Physical Constants and Nuclear Properties

| | | | |
|---|---|---|---|
| Chemical Formula | | | K |
| Atomic Number | | | 19 |
| Atomic Weight | | | 39.10 |
| Melting Temperature | | | 145.8°F |
| Boiling Temperature (1 atm) | | | 1393.9°F |
| Absorption Cross Section to 0.025 ev (thermal) Neutrons | | | 2.1 b |
| Total Cross Section to 0.025 ev Neutrons | | | 4.3 b |
| Ionization Potential | | | 4.318 volt |
| Natural Isotopes (Mass Number) | 39 | 40 | 41 |
| Isotopic Abundance | 93.10% | 0.012% | 6.88% |

Radionuclides of Potassium:

| Mass | Half-Life | Decay Mode | Energy (Mev) | Decay Product |
|---|---|---|---|---|
| 37 | 1.2 s | $\beta^+$ | 5.1 | $Ar^{37}$ |
| 38 | 7.7 m | $\beta^+$, $\gamma$ | 2.7, 2.2 | $Ar^{38}$ |
| | 0.95 s | $\beta^+$ | 5.1 | $Ar^{38}$ |
| 40 | $1.25 \times 10^9$ y | $\beta^-$ | 1.32 | $Ca^{40}$ |
| | | EC,[a] $\gamma$ | 1.46 | $Ar^{40}$ |
| 42 | 12.4 h | $\beta^-$<br>$\gamma$ | 3.53, 2.01<br>1.53, 0.31 | $Ca^{42}$ |
| 43 | 22 h | $\beta^-$<br>$\gamma$ | 0.24, 0.46, 0.83, 1.22, 1.84<br>0.220, 0.371, 0.388, 0.394, 0.591, 0.614, 1.01 | $Ca^{43}$ |
| 44 | 22 m | $\beta^-$<br>$\gamma$ | 1.5, 4.9<br>1.13, 2.67, 2.48, 3.6 | $Ca^{44}$ |
| 45 | 20 m | $\beta^-$<br>$\gamma$ | ?<br>0.18, 1.7 | $Ca^{45}$ |

[a]Orbital electron capture.

# THERMODYNAMIC PROPERTIES

The thermodynamic properties characterize a substance with respect to equilibrium states. In this category, we include the critical state conditions and sonic velocity, the PVT relationships (vapor pressure, density, and compressibility), the enthalpy, heat capacity, latent heats of phase change, and entropy, and the surface tension.

The vapors of many metals do not behave as ideal gases because the molecular weights of such vapors change with changing conditions. This arises from variations in the relative amounts of monomer, dimer, trimer, etc., species present in the vapor as the temperature changes. Since a certain amount of energy is tied up in these polymeric states, it is necessary to account for these vapor species composition effects in calculating the thermodynamic properties of the vapor. When this is done, the properties are known as equilibrium properties. On the other hand, when processes occur rapidly – as in the nozzle expansion of a vapor – equilibrium between the several vapor species may not be achieved within the physical confines of the pertinent component. Calculations are then based on a fixed vapor composition, and the properties are known as frozen properties. Generally, under conditions of shifting equilibrium, bracketing calculations are made using the extremes of equilibrium and frozen properties.

## Critical Properties

The critical properties of potassium are important in the design of vapor compressors and turbines and useful in the estimation of the transport properties. Further, some generalization of the properties of different substances is possible through the use of the reduced state concept (ratio of a given state to the critical state).

Except for mercury,[1,2] the critical properties of the liquid metals have not been measured; and therefore, it has been necessary to resort to various methods for estimating these properties. Available predicted values for potassium are compared in Table 2. Both Grosse[3] and Morris[4] used the method of corresponding states (due to van der Waals) which requires, for example, that the entropies of vaporization of various liquids should be equal at corresponding reduced temperatures ($T_r = T/T_{crit}$). Grosse combined this with the law of rectilinear diameter, an empirical statement that the mean density – $\frac{1}{2}(\rho_{liq} + \rho_{vap})_{sat}$ – decreases linearly with temperature and that at $T_{crit}$, $\rho_{liq} = \rho_{vap}$. He then used information on mercury[5] to develop the critical properties of the alkali metals. Novikov[6] estimated the critical temperatures of the alkali metals using the van der Waals relationship,

$$T_{crit} = \frac{8}{27R}\,(a/b) \quad ,$$

and the additivity of the van der Waals constants a and b in chemical compounds. He claims good accuracy based on a comparison of calculated and measured (literature) values for mercury. Grosse[7] discounted Novikov's results using arguments based on the law of rectilinear diameter and on the predicted compressibility factor.

Dillon et al.[8] measured liquid and vapor densities between room temperature and up to or near the critical temperature for Na, Cs, and Rb; experimental difficulties precluded measurements with potassium beyond 1200°C. The data were analyzed using a variety of techniques (rectilinear diameter, Rowlinson plots, Kordes plots, and a generalized correlation of reduced density versus reduced temperature).

For critical temperature and critical volume, Dillon's error span encompasses the predictions of Grosse and Morris; and Dillon's estimations are recommended. For the critical pressure, Dillon extrapolated the vapor pressure results of Bonilla et al.;[9] however, as discussed subsequently in the section on Vapor Pressure, Bonilla's results are somewhat higher than the currently recommended values. The base used by Grosse in obtaining the critical pressure was not stated; Grosse also states that, in general, his predictions of $P_{crit}$ are the most uncertain. We, therefore, suggest at present Dillon's value for $P_{crit}$.

## Sonic Velocities

Liquid. The velocity of sound in liquid potassium at its melting point has been reported by Kleppa;[10] this is shown in Table 3 and can be expressed by the equation:

$$c_K = 1820 - 0.5\ T \quad ,$$

where $c_K$ is in m/sec and T in °C. Trelin et al.[11] claim, without elaboration, that the data of Kleppa "contain a large systematic error" and proceed to measurements of their own. They obtained no data on potassium but reported values for sodium and NaK-75. Trelin's results for sodium at its melting temperature (97.82°C) is ~10% greater than the value reported by Kleppa. Since Kleppa made no measurements on NaK, further comparison between the two investigators is not possible. Hence, there is no basis for assuming at this time that Kleppa's results for potassium are incorrect.

Vapor. Equilibrium and frozen sonic velocities for saturated vapor are shown in Fig. 1 and listed in Table 3. The curves plotted were taken

from the calculations of Shapiro and Meisl[12] as reported by Weatherford et al.[13] No experimental values were found.

## PVT Relationships

### Introduction

As noted above, the vapors of the alkali metals are known to contain molecular species of two or more atoms. For potassium, spectroscopic information indicates the presence of $K_2$ (dimer) and $K_4$ (tetramer) in sufficient abundance to affect the calculation of vapor thermodynamic properties. The composition of the vapor is described by a condition of mobile equilibria; i.e., the relative amounts of K, $K_2$, and $K_4$ present in the vapor varies with the temperature.

Two general methods are used to derive the enthalpy, entropy, and heat capacity from experimental PVT data. The quasi-chemical method considers the gas as a mixture of molecular species and derives equilibrium constants for the mobile equilibria. The equation of state is constituted by equations of the form:

$$\log k_i = A_i + B_i/T$$

$$i = 2, 4 \text{ for potassium}$$

$$PV = RT/M_a$$

$$M_a = \text{equilibrium molecular weight}$$

These equations can then be used to obtain the other thermodynamic functions; see Ewing et al.[14] for further discussion. The virial equation method treats the vapor as a monatomic assembly with all apparent imperfections given by a virial equation of state. This equation is of the form:

$$\frac{P\tilde{V}}{RT} = A + \frac{B}{V} + \frac{C}{\tilde{V}^2} + \frac{D}{\tilde{V}^3} + \ldots ,$$

where A, B, C, D, ... are functions of temperature and $\tilde{V}$ is the molal volume. The virial coefficients are obtained by graphical or least-squares fit of the PVT data. The other thermodynamic properties are then developed as corrections to the monatomic gas in terms of these virial coefficients (see Ewing et al.[14]).

The starting point for the calculation of any particular property is the absolute value of that property either as saturated liquid or as monomeric gas at 1 atm. Calculations then proceed along constant temperature lines. By way of example, following the monomer gas path, the vapor enthalpy at any pressure is determined by adding the enthalpy change to the corresponding absolute enthalpy for the ideal gas at 1 atm. The enthalpy of saturated liquid is then obtained by subtracting the enthalpy of vaporization from the saturated vapor enthalpy. Conversely, following the liquid path, the saturated vapor enthalpy is found by adding the enthalpy of vaporization to the corresponding absolute enthalpy of the liquid. The enthalpy at any state in the superheat region is then obtained by adding the enthalpy change to the enthalpy of the saturated vapor.

Ewing et al.[14] results show that calculations made by either the quasi-chemical or virial methods are effectively equivalent. However, for several reasons, they prefer the virial method. Further, they state that valid comparison between the two computational paths can be made only for temperatures below 2200°F, since this temperature is the limit for measured liquid heat capacities. In the range 1000 to 2000°F, absolute enthalpies in the superheat region based on saturated liquid were 0.8 to

1.1% lower than values based on monomeric gas enthalpies, entropies were 0.3 to 0.5% lower, and heat capacities were 1 to 5% lower. Ewing suggests that this relatively constant error probably derives from small errors in a base property in one or both paths. For the gas path, he suggests that this error may be in the heat of vaporization of solid potassium at 0°R. For the liquid path at temperatures above 2400°F, the severe discrepancy between the values computed by the two paths (e.g., $C_p$ values are 21 to 45% lower than determined by the monomer gas path) is attributed to (1) extrapolation of measured liquid $C_p$ values and (2) small errors in the enthalpy of vaporization occasioned by the extrapolation of the virial equation above 2375°F. Because of this, Ewing recommends the monomer gas path results.

Equation of State

The several available equations of state are listed in Table 4. The equations of Lemmon et al.,[15] Achener et al.,[16] and Ewing et al.[14] are based on a graphical or least-squares fit to the investigator's own experimental PVT data. Heimel[17] developed his equation of state as follows: (1) the second virial coefficient, B, was based on a curve fit for the average Rydberg potential as given by Davies et al.,[18] (2) the third and fourth virial coefficients, C and D, were expressed in terms of B, (3) the six constants appearing were reduced to two by assuming a hard-sphere potential model for potassium vapor, and (4) the final two constants were obtained by fit to the PVT data of Ewing et al.[14] Hicks[19] treated the vapor as a monatomic, imperfect gas and used an equation of state of the form

$$PV = RT + B'P \quad ,$$

where all deviation from ideality is described by the coefficient $B'$, a quantity closely related to the second virial coefficient. $B'$ is represented by the function, $b/T^m$; with b and m being evaluated empirically from vapor-pressure data. Hicks used low-temperature vapor-pressure data primarily to obtain b and m; the values of these constants for potassium are given in Eq. (5) of Table 4.

The equation of Ewing et al.[14] is recommended; further comments supporting this choice are found in following sections on Compressibility Factor, Vapor Pressure, and Vapor Density.

## Vapor Pressure

Twelve equations for the vapor pressure of potassium are listed in Table 5. For the subatmospheric pressure region (<1400°F), the equation of Ditchburn and Gilmour[20] [Table 5, Eq. (6)] is recommended; this equation is based on a critical synthesis of the results of 12 early (prior to 1941) investigators. At temperatures above 1400°F, the equation of Ewing et al.[14] [Table 5, Eq. (5)] is recommended with the rationale that it is a part of an internally consistent set of thermodynamic data. In Fig. 2, the equation of Ewing et al. is plotted over the full temperature range, 1100 to 2500°R. For the region below 1400°F, the Ditchburn and Gilmour equation deviates from the Ewing equation as follows:

| Temperature (°R) | Deviation (%) |
|---|---|
| 1853.5 | -3.33 |
| 1700 | -4.36 |
| 1500 | -5.86 |
| 1300 | -7.71 |
| 1100 | -9.90 |

A comparison between the several more recent high-temperature measurements shows the following:

| Eq. No.[a] | Investigator | Vapor Pressure (psia) 1393.9°F | 1700°F | 2300°F |
|---|---|---|---|---|
| 2 | Lemmon | 14.05 | 55.48 | 348.7 |
| 3 | Rigney | 14.23 | 55.65 | 333.3 |
| 4 | Achener | 14.38 | 55.92 | 333.6 |
| 5 | Ewing | 14.70 | 56.79 | 327.8 |
| 6 | Ditchburn & Gilmour | 14.21 | – | – |
| 7 | Makansi | 15.04 | 57.14 | – |
| 8 | Heimel | 14.55 | 56.63 | 328.5 |
| 11 | Grachev & Kirilov | 9.87 | 44.20 | 311.0 |
| 12 | Thorn & Winslow | 13.73 | 53.15 | – |
| 13 | b | 14.90 | 57.22 | – |

[a]Equation numbers as listed in Table 5.
[b]Data of Makansi as reevaluated by Thorn & Winslow.

As noted above, the recommended equations show a 3.3% mismatch at the atmospheric boiling temperature given by Ewing (1393.9°F). A similar comparison between the Heimel[17] and the Ditchburn and Gilmour[20] equations [using Heimel's value for the normal boiling temperature (1396°F)] gives for P, 14.7 and 14.36 psia, respectively; the disagreement is only 2.3%. The general agreement between Ewing and Heimel is excellent over the full range of comparison – +1.02% at 1394°F, +0.28% at 1700°F, and -0.21% at 2300°F.

The equations of Rigney[21] and Achener[16,22] compare closely over the temperature range and are in reasonable agreement with Ewing except at the

higher temperatures. The equation of Lemmon[15] shows an even greater deviation from Ewing (-4.4% at 1394°F and +6.4% at 2300°F). The results of Grachev and Kirilov[23] are extremely low over the entire range and are presumed to be erroneous. Makansi et al.[24] give values which are somewhat higher than Ewing. Thorn and Winslow[25] reevaluated the data of Makansi by weighting values of log P by $P^2$ (corresponds to unweighted treatment of pressure) and obtained Eq. (13); the comparison with Ewing is not significantly affected. These same authors (Thorn and Winslow) then used an imperfect gas model along with the spectroscopically observed dissociation energy to obtain the second virial coefficient as a correction to the revised Makansi results and the unpublished data of Johnson et al. (Ref. 25, Note 7). The agreement with Ewing is only fair.

It is interesting to note that the equation of Lemmon et al. [Eq. (1)] is the same as Eq. (12) developed by Thorn and Winslow with the addition of the terms:

$$\frac{8}{T} + \frac{7.40 \times 10^4}{T} e^{-1.056 \times 10^4/T} \quad .$$

Lemmon states that the Battelle functional representation was based on the Thorn-Winslow relation supplemented by an extrapolation procedure, described by Walling et al.,[26] with the inclusion of third virial effects.

Hicks,[19] in obtaining the equation of state described in the previous section, defined a quantity Q as follows:

$$Q = \Delta H^o_{298.15} + b\, P/T^m \quad ,$$

where Q was evaluated from the free-energy function $[-(F^o_T - H^o_{298.15})/T]$ as given by Stull and Sinke[27] and modified by Hicks and from the low

temperature vapor pressure data of Neumann and Völker,[28] Edmondson and Egerton,[29] Fiock and Rodebush,[30] Ruff and Johannsen,[31] Heycock and Lamplough,[32] and Kröner[33] and the higher temperature data of Makansi et al.[24] The intercept (at $P/T^m = 0$) of the straight line fitted to the data on a Q versus $P/T^m$ plot gives $\Delta H^o_{298.15}$; for potassium this was found to be 21,415 ± 50 cal/g-atom. Hicks tabulates Q and lists vapor pressures as a function of temperature as follows:

| Temperature | | Q | Presssure (atm) | |
|---|---|---|---|---|
| (°K) | (°R) | (cal/g-atom) | Hicks[19] | Ewing[14] |
| 500 | 900 | 21,414 | $2.79 \times 10^{-5}$ | $3.32 \times 10^{-5}$ |
| 600 | 1080 | 21,407 | $8.36 \times 10^{-4}$ | $9.64 \times 10^{-4}$ |
| 700 | 1260 | 21,381 | $9.37 \times 10^{-3}$ | $10.56 \times 10^{-3}$ |
| 800 | 1440 | 21,321 | $3.74 \times 10^{-2}$ | $6.30 \times 10^{-2}$ |
| 900 | 1620 | 21,224 | $2.37 \times 10^{-1}$ | $2.51 \times 10^{-1}$ |
| 1000 | 1800 | 21,099 | $7.37 \times 10^{-1}$ | $7.53 \times 10^{-1}$ |
| 1100 | 1980 | 20,967 | 1.85 | 1.84 |
| 1200 | 2160 | 20,852 | 3.92 | 3.86 |
| 1300 | 2340 | 20,770 | 7.26 | 7.21 |

As noted from the final column in this table, agreement with Ewing et al.[14] is acceptable. The prediction of vapor pressures at higher temperatures depends on extended calculation or extrapolation of Q as a function of temperature.

Liquid Density

The equation given by Ewing et al.[14] [Table 6, Eq. (1) and Fig. 3] is recommended.

The recommended equation was derived by Ewing as a "best fit" to the determinations of Hagen[34] and Ewing et al.[14,35] at the lower temperatures, to those of Jackson et al.,[36] Novikov et al.,[37] and Rinck[38] at the intermediate temperatures, and to those of Ewing et al.[14] at the higher temperatures. The maximum deviation of the results of these measurements from the recommended equation is -0.81% (Rinck); the bulk of the data are represented to within ±0.2%. A confidence limit of ±0.2 to ±0.4% is ascribed. The Ewing et al.[14] high-temperature data (1009 to 2287°F) show an average deviation from the recommended equation of ±0.12% with a probable error in the experimental measurements of ±0.25 to ±0.30%. The agreement in liquid density values determined by the several equations of Table 6 is within 1%.

Vapor Density

Ewing et al.[14] measured specific volumes of nine saturated vapor states between 1570 and 2376°F. The equation,

$$\log_{10}\left[\frac{RT_s}{M_1 P_s} - V_{g,s}\right] = \frac{4168}{T_s} - 1.8433 \quad ,$$

was fitted to the observed data with an average deviation of ±0.34%, where

$T_s$ = saturation temperature (°R),

$P_s$ = saturation pressure (atm),

$V_{g,s}$ = specific volume of saturated vapor ($ft^3/lb_m$),

$R$ = gas constant (1546 $ft \cdot lb_f/lb\text{-}mole \cdot °R$),

$M_1$ = monomer molecular weight (39.1 $lb_m/lb\text{-}mole$).

An extrapolation procedure is involved in obtaining the intersection of saturated and superheated vapor curves; and Ewing believes that saturated specific volume obtained from the virial equation [Table 4, Eq. (3)] and the vapor-pressure equation [Table 5, Eq. (5)] will be of higher reliability than those determined from the above equation. However, a comparison between virial equation computed values and observed values showed an average deviation of only ±0.33%.

Vapor densities can also be determined from other state and vapor pressure equations given in Tables 4 and 5, respectively. In particular, Lemmon et al.,[15] Achener et al.,[16] and Heimel[17] results can be used. These equations were compared and discussed in preceding sections. Saturated vapor specific volumes calculated by Ewing are graphed in Fig. 4; superheat values from the same source are tabulated in Appendix B.

Liquid Compressibility

Values for the adiabatic and isothermal compressibility of liquid potassium at 147°F are given in Table 7; these data were derived by Kleppa[10] from sonic velocity measurements.

Vapor Compressibility

The quantity PV/RT is designated as z, the compressibility factor, and is a measure of the nonideality of the vapor. Heimel[17] calculates somewhat higher values (~1%) for saturated vapor than does Ewing et al.,[14] though the results of both analyses agree acceptably with Ewing's limited experimental data (9 points). The experimental data of Lemmon et al.[15] and of Achener et al.[16] are not presented in a form for convenient comparison; however, their results show values of z which differ from those of Ewing and of Heimel by no more than 2%.

Saturation values according to Ewing et al.[14] [Table 4, Eq. (3)] are plotted in Fig. 5; values for superheated vapor (also from Ewing) are tabulated in Appendix B.

Isentropic Expansion

Goldman[39] reports experimental data on the isentropic expansion index, $\gamma_s$, as: 1.33 at 1697°R, and 1.42 at 1892°R.

Heimel[17] calculated from his developed equation of state [Table 4, Eq. (4)]: 1.434 at 1800°R, and 1.436 at 1980°R.

## Enthalpy and Entropy

A general discussion on the methods used in deriving the enthalpy, entropy, and heat capacity relationships from basic PVT data was given in the introductory portion of the preceding section on PVT Relationships.

Liquid Enthalpy

Only two sets of experimental data are available for the enthalpy of liquid potassium; namely, measurements by Lemmon et al.[15] and by Douglas et al.[40] These are shown by Eqs. (1) and (2), respectively, in Table 8. Lemmon reports enthalpies that are, on the average, 1.25% higher than those obtained by Douglas. Equation (3) in Table 8, given by Ewing et al.[14] as the starting point for liquid path calculations, is derived directly from the work of Douglas using the absolute enthalpy of solid potassium at 32°F from Evans et al.[41] (1525 cal/g-mole). This equation is shown as the lower curve in Fig. 6.

Ewing et al.[14] recommend, however, liquid enthalpies based on monomer gas calculations. As described previously, the enthalpy of vaporization is subtracted from the enthalpy of the saturated vapor to give the saturated

liquid enthalpy. This is discussed further in a following paragraph on vapor enthalpy. The results, tabulated by Ewing for temperatures above 1400°F, are shown by the upper curve in Fig. 6 and lie about 3% above the experimental values.

We recommend for liquid enthalpy the experimental results as expressed by Eq. (3).

Vapor Enthalpy

The enthalpy of saturated vapor calculated by Ewing et al.[14] is plotted in Fig. 7 and listed in Table 9. The results were obtained by Ewing and co-workers through a monomer-gas-path thermodynamic calculation using their experimental PVT data. Thus, the enthalpy is expressed as:

$$H_g^T = H_g^o + \frac{RT}{M_1}\left\{\frac{1}{\tilde{V}}\left[B - T\left(\frac{dB}{dT}\right)\right] + \frac{1}{\tilde{V}^2}\left[C - T\left(\frac{dC}{dT}\right)\right] + \frac{1}{\tilde{V}^3}\left[D - T\left(\frac{dD}{dT}\right)\right]\right\} ,$$

where $M_1$ is the molecular weight of the monomer (39.1) and the virial coefficients are as given in Eq. (3) of Table 4. The reference value for the monomeric gas at 1 atm (relative to the solid at 0°R) is:

$$H_g^o = 998.95 + 0.12700\ T + 24{,}836\ e^{-39{,}375/T} ,$$

for H in Btu/$lb_m$ and T in °R. This was derived using the work of Evans et al.[41] for the standard enthalpies of monomeric gas between 0 and 3300°F and for the enthalpy of vaporization at 0°R (21.70 mean Kcal/mole). Agreement with values calculated by the liquid path is to within 1%. Vapor enthalpies were also computed by Ewing using the quasi-chemical method (principally as a check on the virial method); agreement was generally excellent (within 0.5%). Values of the enthalpy for saturated vapor are shown as Eq. (2) in Table 9.

Heimel[17] determined the real-gas enthalpy, $H_T$, along the saturation line by adding the relative function,

$$(H - H^o)_T = \left(B - T\frac{dB}{dT}\right) P + \left(C - T\frac{dC}{dT}\right)\frac{P^2}{2} + \left(D - T\frac{dD}{dT}\right)\frac{P^3}{3} ,$$

to the corresponding function for the ideal monomer, $H_T^o$. The virial coefficients are as given in Eq. (4), Table 4; the pressure is as given by Eq. (8), Table 5; and the enthalpy of the ideal monomer is calculated from:

$$H_T^o = (H_T^o - H_{298}^o)_{monomer} - (\Delta H_{298}^o)_{vaporization} ,$$

where $(H_T^o - H_{298}^o)_{monomer}$ is tabulated in Ref. 17 (Table II) and the average value of $(\Delta H_{298})_{vaporization}$ = 21.1846 Kcal/mole. Results for the real gas are given as Eq. (3) in Table 9; these values were taken from Table VIII of Ref. 17.

Achener et al.[16] added to the values for saturated liquid enthalpy, reported by Douglas et al.[40] [Table 8, Eq. (2)], their measured values for the enthalpy of vaporization[42] to obtain the enthalpy of the saturated vapor as shown by Eq. (1), Table 9. The enthalpy of the solid at the standard state (298°K) was taken to be zero.

Walling and Lemmon[43] followed a similar procedure using the data of Deem et al.[44] for the liquid potassium enthalpy adjusted to 0°K by adding 1525 cal/mole from the data of Evans et al.[41] and the heat of vaporization calculated by the Clapeyron equation (Walling et al.[26]). Values taken from Ref. 15, Table A-1, are listed as Eq. (4) in Table 9. The enthalpy appears to achieve a maximum at a temperature of about 2000°R; this result contrasts with the data reported by other investigators.

A comparison of absolute enthalpies follows:

| Temperature (°K) | Enthalpy (Kcal/mole) | | | |
|---|---|---|---|---|
| | Achener | Ewing | Heimel | Lemmon |
| 800 | – | – | 23.44 | 25.35 |
| 1000 | 23.23 | – | 23.89 | 25.76 |
| 1200 | 23.90 | 26.10 | 24.21 | 25.75 |
| 1400 | 24.69 | 26.50 | 24.47 | 24.83 |
| 1600 | – | 26.88 | 24.75 | – |

Achener and Heimel used 298.15°K as the standard state, while Ewing and Lemmon used 0°K. From the values published by Evans et al.,[41] the enthalpy change between 0°K and 298.15°K is 1.48 Kcal/mole. Using this to adjust the Heimel results, the discrepancy between the Heimel and Ewing saturated vapor enthalpies varies from 1.7 to 2.6% at the listed comparable temperatures. Most of the remaining difference can be accounted for by the values used for the latent heat of vaporization at the standard condition. Similarly, Achener's results vary from Heimel's by +2.8 to -0.9%.

A much more severe discrepancy is apparent in the relative enthalpies. Thus, the enthalpy differences (Kcal/mole) between 1200 and 1400°K and between 1400 and 1600°K are as follows:

| | 1200°K | 1400°K | 1600°K |
|---|---|---|---|
| Ewing | +0.40 | +0.38 | |
| Heimel | +0.26 | +0.28 | |
| Achener | +0.79 | +0.91 | |
| Lemmon | -0.92 | – | |

It is currently recommended that Ewing's values be used.

The enthalpy of superheated vapor, tabulated in Appendix B, was taken from Ewing et al.[14] Lemmon and Achener also list values. Heimel shows saturation values only; however, superheated vapor enthalpies could be computed, with some labor, from the results given.

Latent Heat of Vaporization

The only available experimental results are those of Achener et al.[42] Ewing et al.[14] calculated values using the Clausius-Clapeyron relationship with NRL experimental data for $dP/dT$, $V_g$, and $V_\ell$. Lemmon et al.[15] performed a similar calculation using BMI data. Rigney et al.[21] also made a Clausius-Clapeyron calculation using P&WA vapor pressures and Ewing et al.[14] (NRL) and Hall and Blocher[45] (BMI) volume relationships. Heimel[17] determined the enthalpy of vaporization as:

$$(\Delta H_T)_{vaporization} = (H_T)_{monomer} - (H_T^o)_{liquid} \quad .$$

Heimel reports that his calculated values and those of Ewing agree very closely and differ from Achener's experimental values by 3.5% maximum. Ewing's results [Table 10, Eq. (3), and Fig. 8] are recommended as a part of a consistent set of thermodynamic data.

Liquid Heat Capacity

Results of three investigators are given in Table 11.

Douglas et al.[40] calculated the heat capacity along the saturation line from the relative enthalpy using the relation:

$$C_{p,s} = \frac{dH}{dT} - V \frac{dP}{dT} \quad ;$$

the correction term, $V(dP/dT)$, was found to be relatively small even at 800°C (the upper temperature limit of the enthalpy measurements).

Douglas expressed this correction as a function of $T^2$ and combined it with the $T^2$ term resulting from differentiation of the enthalpy equation.

Nikol'skii et al.[46] show three experimental points obtained at temperatures between 125 and 400°C; the values listed as Eq. (2) of Table 11 are from a smoothed curve through these data.

Lemmon et al.[15] used the density data of Ewing et al.[47] and the vapor pressure data of Walling et al.[43] to obtain:

$$V \frac{dP}{dT} = 0.003 - 0.0307 \times 10^{-4}\ T + 0.0436 \times 10^{-7}\ T^2 \quad ,$$

where the correction term is in units of cal/g·°C and T in °C.

To a temperature of 400°C (750°F), all three sets of data are in good agreement (< 1%). The discrepancy between Lemmon and Douglas progressively increases above 400°C, until at 800°C (the upper temperature limit on the Douglas data) the heat capacity determined by Lemmon is 6.4% above that obtained by Douglas. This difference is somewhat greater than the ±5% error estimate given by Lemmon for data in this range. It must also be noted that Lemmon developed the correction term, V(dP/dT), using the earlier, incorrect density data of Ewing et al.[47] Evans et al.[41] extrapolate the low and intermediate temperature data of a number of investigators to 727°C and tabulate values which agree closely with Douglas to about 600°C.

The results of both Lemmon et al. [Eq. (1)] and Douglas et al. [Eq. (3)] are shown in Fig. 9. Since Douglas' liquid potassium data have been used by several investigators in obtaining other liquid and vapor thermodynamic properties, we recommend this equation to 1472°F. Extrapolation beyond this temperature is risky; the dashed line in Fig. 9 gives possible values using the limited Ewing observations (3 points) as a guide.

Vapor Heat Capacity

Heat capacities for saturated potassium vapor are given in Table 12. Ewing et al.[14] calculated values from a virial equation (monomer gas path) derived from the enthalpy equation shown above. Heat capacities obtained by the liquid path were 1 to 5% lower than those determined by the gas path. Lemmon et al.[15] state that $C_p$ was calculated on a digital computer and tabulate values at arbitrary temperatures; their results differ significantly from Ewing's (~10% higher at 1400°F and nearly 100% at 2200°F). Achener et al.[16] [Table 12, Eq. (4)] calculate saturated vapor heat capacities that also differ somewhat from those reported by Ewing, about -10% at 1400°F and +30% at 2000°F. Achener states that the specific heats reported were calculated from a base of 0.0002 atm. Heimel[17] tabulates values that are about 4% lower than Ewing's at 1400°F and about 10% higher at 2200°F. However, he points out that Ewing's analysis predicts a gradual rise in $C_p$ between 1800 and 2150°R followed by a gradual decline to 2700°R and finally a sharp increase above 2700°R. In contrast, the hard sphere potential model used by Heimel shows first a gradual increase and then a gradual decline through this temperature range with a maximum at about 2500°R.

Ewing's values for saturated vapor are currently suggested; these are shown as Eq. (2) in Table 12 and in Fig. 10. Values from Ewing for superheated vapor are given in Appendix B.

Liquid Entropy

Two equations for liquid entropy are given in Table 13: Eq. (1), Douglas et al.[40]; and Eq. (2), Ewing et al.[14] These equations were developed by integrating $C_{p,liq}/T$ (see Table 11) over the desired temperature range.

Ewing's equation is based on Douglas' liquid heat capacity data with extrapolation to higher temperatures using the limited NRL heat capacity measurements (see discussion above and Fig. 9). It was arbitrarily assumed in deriving Eq. (2), Table 12, that liquid potassium does not contain significant polyatomic species. Lemmon et al.[15] list absolute liquid entropies [Eq. (3), Table 13] derived by appropriate integration of the heat capacity relation and the addition of 17.816 cal/mole·°K (0.4557 Btu/$lb_m$·°R) as given by Evans et al.[41] Lemmon's results are in close agreement with Ewing, varying from -0.14% at 1200°R to +1.03% at 2600°R.

Ewing's equation is recommended and is graphed in Fig. 11.

Vapor Entropy

The discussion on vapor entropy follows generally as given for vapor enthalpy. Values calculated by four investigators are shown in Table 14.

Ewing et al.[14] expresses the vapor entropy as:

$$S_g^T = S_g^o - \frac{R}{M_1}\left\{ \ln P - \ln \frac{P\tilde{V}}{RT} + \frac{1}{\tilde{V}}\left[B + T\left(\frac{dB}{dT}\right)\right] + \frac{1}{2\tilde{V}^2}\left[C + T\left(\frac{dC}{dT}\right)\right] + \frac{1}{3\tilde{V}^3}\left[D + T\left(\frac{dD}{dT}\right)\right]\right\} ,$$

where $M_1$ is the monomer molecular weight, P is the pressure, $\tilde{V}$ is the molal volume, and the virial coefficients B, C, and D are as given by Eq. (3), Table 4. The reference value for the monomeric gas at 1 atm (relative to the solid at 0°R) is:

$$S_g^o = 0.18075 + 0.12700 \ln T + 0.7617\, e^{-31,126/T} ,$$

for S in Btu/$lb_m$·°R; this is based on the standard entropies of Evans et al.[41] for the monomeric gas between 0 and 3300°F. Agreement with

values calculated by (1) the liquid path was to within 0.5% and (2) the quasi-chemical method, to within 0.1%. Saturated vapor entropies are given as Eq. (2) in Table 13.

Achener et al.[16] obtained the entropy of the saturated vapor by adding to the entropy of saturated liquid, as given by Douglas et al.,[40] the values determined for the entropy of vaporization by AGN.[22] The entropy for the solid state (298°K) was taken as 15.48 cal/mole·°K, and the entropy of melting was taken as 1.67 cal/mole·°K; these values were from Hultgren.[48]

Heimel[17] determined the real gas entropy, $S_T$, on the saturation line by adding the relative function, $(S - S^o)_T$, to the corresponding function for the ideal monomer, $S_T^o$. Thus:

$$(S - S^o)_T = -R \ln P - \frac{dB}{dT} P - \left(\frac{dC}{dT}\right)\left(\frac{P^2}{2}\right) - \left(\frac{dD}{dT}\right)\left(\frac{P^3}{3}\right)$$

and

$$S_T^o = (S_T^o - S_{298}^o)_{monomer} - (\Delta S_{298}^o)_{vaporization} \quad .$$

The virial coefficients are given in Table 4 by Eq. (4); the pressure is as given in Table 5, Eq. (8). $S_T^o$ is presumably calculable from values listed in Table II, Ref. 17. Results for the real gas are given as Eq. (3) of Table 13.

Walling and Lemmon[43] obtain the vapor entropy by adding the entropy of vaporization to the liquid entropy. The latter was found by integration of the heat capacity relation with the addition of 17.816 cal/mole·°K (to give the entropy above 0°K). Values from Table A-1 of Ref. 15 are listed as Eq. (4) in Table 13.

A comparison of absolute entropies follows:

| Temperature (°K) | Absolute Entropy (cal/mole•°K) | | | |
|---|---|---|---|---|
| | Achener | Ewing | Heimel | Lemmon |
| 800 | – | – | 48.39 | 48.46 |
| 1000 | 43.56 | – | 44.20 | 44.15 |
| 1200 | 41.30 | 41.46 | 41.54 | 41.21 |
| 1400 | 39.94 | 39.80 | 39.79 | 38.64 |
| 1600 | – | 38.68 | 38.68 | – |

Ewing and Heimel agree closely (~0.2%) over the temperature range of comparison. Both Achener's and Lemmon's results are also within 0.5% of Ewing.

Ewing's results are given in Table 14 and Fig. 12 and are currently suggested for use.

The entropy of superheated vapor is tabulated in Appendix B taken from Ewing et al.[14]

## Surface Tension

The interfacial tensions (solid-liquid and vapor-liquid) of the alkali liquid metals are of importance in situations where free liquid surfaces exist, where liquid transfer is by capillary action (heat pipes), and where heat transfer occurs by boiling. Data by Cooke,[49] by Quarterman and Primak,[50] and by Taylor[51,52] are reported in Table 15. Quarterman and Primark used a capillary rise technique to obtain the surface tension over the narrow temperature range 148 to 302°F; their results were ~20% below those found by Cooke. Taylor used a maximum bubble-pressure technique

(as did Cooke) but noted difficulties in establishing the peak pressure due to fluctuating manometer readings; his results lie between 9% (at 120°F) and 35% (at 932°F) below Cooke's values.

Prediction of the surface tensions of metals through correlation with other, perhaps more easily measured, physical properties has been attempted by a number of investigators. Thus, Stratton,[54] Huang and Wyllie,[55] and Gogate and Kothari,[56] among others, have proposed electronic theories which have been reasonably successful with the alkali metals though suffering somewhat from uncertainties in basic premises. Skapski[57] and Oriani,[58] primarily, have published physicochemical theories that have also been effective though of some doubt due to ignorance as to the nature of the surface structure. Taylor[51] has summarized these theories and examined a number of empirical relationships (Atterton and Hoar,[59] Leadbeater,[60] Schytil,[61] Williams and Murray,[62] etc.) in the light of available theory. The empirical correlations are to be anticipated from the physicochemical theories relating the surface tension directly or indirectly to the cohesive properties of the metal.

An early attempt at surface tension correlation is that of Eötvos[63] and Ramsay and Shields,[64]

$$\sigma \tilde{V}^{2/3} \sim (T_c - T) \quad ,$$

where $\sigma$ is the surface tension, $\tilde{V}$ is the molar volume, T is the temperature at which both $\sigma$ and $\tilde{V}$ are determined, and $T_c$ is the critical temperature. This equation has been found applicable for a large number of homopolar organic and inorganic compounds (where the constant of proportionality is 2.2 erg/g-mole$^{2/3}$·°K) but has not been successful in predictions for liquid metals. Schytil[61] proposed, on theorectical grounds, a similar relationship

between the surface tension and the melting temperature. Other less exact expressions[65-67] have attempted correlation between the surface tension and properties such as the velocity of sound, compressibility, and solid-state elastic modulus.

Guggenheim[68] extended earlier work by van der Waals and showed that the Eötvös relation could be expressed more exactly as,

$$\sigma = \sigma^{o}(1 - T/T_c)^{n} \quad ,$$

where $\sigma^{o}$ is the extrapolation of $\sigma$ to 0°K and the exponent n has the value 11/9 or 1.222 for most organic liquids.

Strauss,[69] following Hildebrand and Scott[70] and Bondi,[71] presents a relation between the surface tension at the melting temperature and the latent heat of vaporization and finds no improvement in correlation by including the molar volume. The resulting straight line, on a log-log plot, correlated surface tensions for 38 of 42 metals; both measured and estimated values were included.

Grosse[72] proposes a form of the Eötvos relation applicable to liquid metals; namely,

$$\sigma^{o}\, \tilde{V}^{o\,2/3} = C\, T_c \quad ,$$

where C was demonstrated to be $\cong$ 0.64 erg/g-mole$^{2/3}$·°K and the superscript zero again refers to conditions at 0°K. Further, the linear relation of Guggenheim[68] (which satisfies the criterion that at the critical temperature the surface tension of any substance is zero) and a knowledge of the critical temperature permits estimation of the temperature coefficient for the surface tension. Thus, Grosse[72] finds for potassium, using $\sigma^{o}$ = 100 dynes/cm and $T_c$ = 2440°K, that $d\sigma/dT$ = -0.041 dynes/cm·°K. In

a later paper, Grosse[3] reports for cubic and tetragonal metals (the alkali metals fall into this category) that

$$\sigma_m = 0.274\ (\Delta H_{vap}/\tilde{V}_m)^{0.931} \quad ,$$

where $\sigma_m$ (dynes/cm), $\Delta H_{vap}$ (cal/g-mole), and $\tilde{V}_m$ ($cm^3$/g-mole) are all evaluated at the melting temperature.

The experimental results of Cooke [Table 15, Eq. (1), and Fig. 13] are currently recommended. Cooke finds, over the temperature range 70 to 710°C, $d\sigma/dT = -0.0646$ dynes/cm·°K.

Jordan and Lane[90] in a recent paper report values for the surface tension of potassium obtained using a vertical-plate balance. Measurements, made at 200°C with silver and zinc plates, gave a mean value for the surface tension of 102.1 dyne/cm and a temperature coefficient of -0.06 dyne/cm·°C. These results are in excellent agreement with Cooke (102.4 dyne/cm at 200°C).

Table 2. Critical Properties

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| Temperature (°K) | | | | | | | |
| $T_c = 2223$ | | | ±330°K | See Comments | Found from density correlation | Dillon et al. (1966) | 8 |
| $T_c = 2300$ | | | | | Corresponding states | Morris (1964) | 4 |
| $T_c = 1770$ | | | | | Used van der Waal's relationship | Novikov (1964) | 6 |
| $T_c = 2450$ | | | ±300°K | | Corresponding states | Grosse (1963) | 3 |
| Pressure (atm) | | | | | | | |
| $P_c = 160$ | | | ±32 atm | See Comments | Equation of Sawney & Bonilla with $T_c$ of Dillon | Dillon et al. (1966) | 8 |
| $P_c = 250$ | | | | | Corresponding states | Morris (1964) | 4 |
| $P_c = 230$ | | | ±24 atm | | Corresponding states | Grosse (1963) | 3 |
| Volume (liter/g-mole) | | | | | | | |
| $V_c = 0.209$ | | | ±0.040 liter/g-mole | See Comments | Measurements to near critical | Dillon et al. (1966) | 8 |
| $V_c = 0.240$ | | | | | Corresponding states | Morris (1964) | 4 |
| $V_c = 0.217$ | | | | | Corresponding states | Grosse (1963) | 3 |

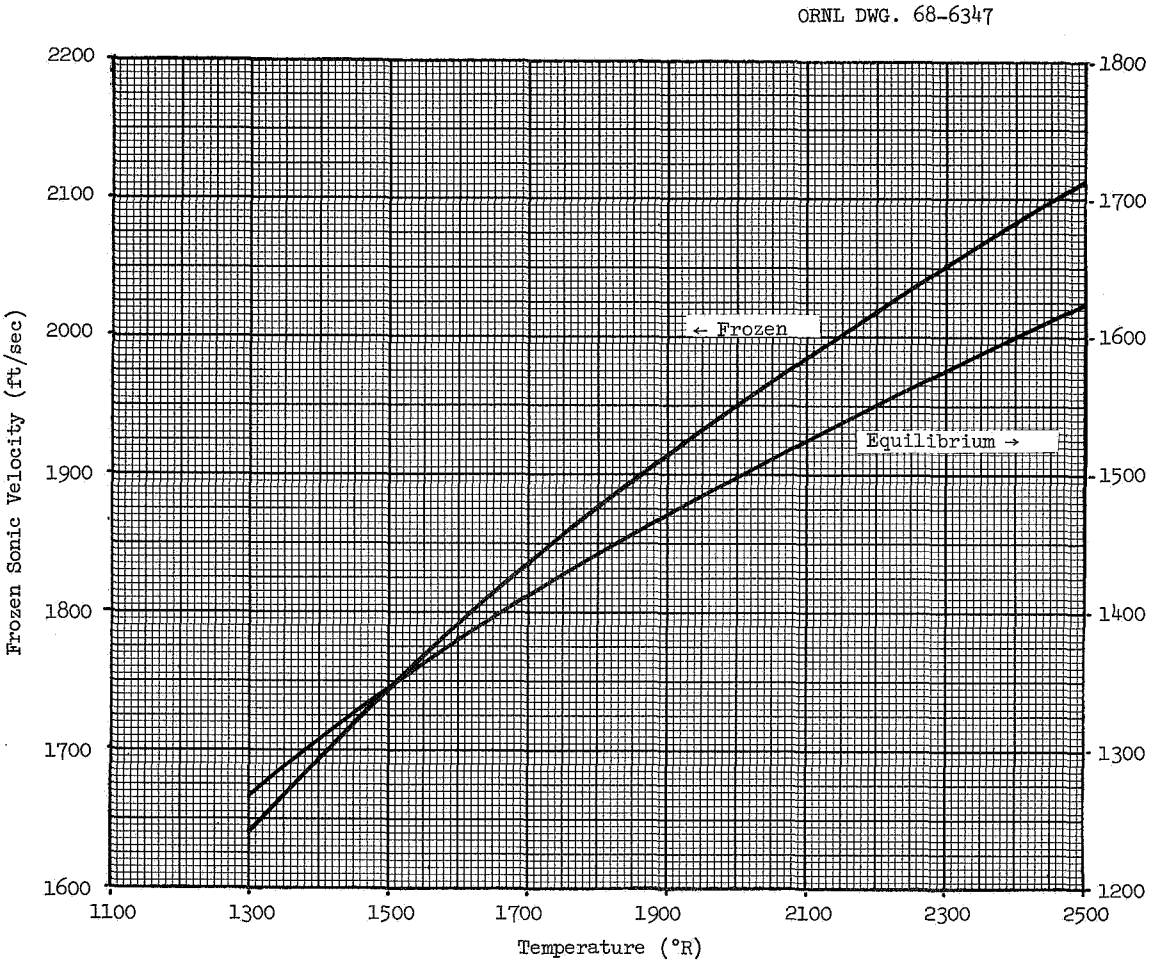


Fig. 1. Potassium: Saturated Vapor Sonic Velocity.

Table 3. Sonic Velocity, Saturated Phases

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| Liquid<br>$v = 1820 - 0.5\ T$<br>[v = m/sec; T = °C] | | mp–320 | ±20 m/sec | Electronic pulse-circuit | Sample contained 0.5% Na and minor amounts of Rb and Fe | Kleppa (1950) | 10 |
| Vapor<br>Temp. (°R) / Equilibrium (ft/sec) / Frozen (ft/sec)<br>1300 / 1268.1 / 1641.3<br>1500 / 1346.0 / 1745.5<br>1700 / 1412.5 / 1835.1<br>1900 / 1471.6 / 1914.3<br>2100 / 1525.1 / 1985.2<br>2300 / 1576.0 / 2051.5<br>2500 / 1624.4 / 2113.6 | | | | Calculated | | Shapiro & Meisl (1960) | 12 |

Table 4. Equation of State

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $\frac{PV}{nRT} = 1 + B'P + C'P^2$<br>$\log_{10} \lvert B \rvert = 8.912 + \frac{1.471 \times 10^3}{T} - 2.212 \log_{10} T$<br>$B' = - B/82.057\ T$<br>$\log \lvert C' \rvert = - 6.315 + \frac{4.670 \times 10^3}{T}$<br>$C' < 0$<br>[P = atm; T = °K; V = $cm^3$; n = No. g-atomic weights] | (1) | 1584–2104 | | PVT-Fixed Volume Apparatus | | Lemmon et al. (1963) | 15 |
| $\frac{P}{RT} = \left( \frac{1}{\tilde{V}} + \frac{B}{\tilde{V}^2} + \frac{C}{\tilde{V}^3} + \frac{D}{\tilde{V}^4} + \frac{E}{\tilde{V}^5} + \frac{F}{\tilde{V}^6} \right)$<br>$B = - 0.13019\ T^{0.5}\ e^{7000/T}$<br>$C = - 1.2388 \times 10^7\ e^{900/T}$<br>$D = - 1.4179 \times 10^{11}\ e^{1000/T}$<br>$E = 7.9205 \times 10^{15}$<br>$F = - 3.5099 \times 10^{19}$<br>[P = atm; T = °K; $\tilde{V}$ = $cm^3$/mole]<br>[R = 82.056 $cm^3$·atm/°K·mole] | (2) | 1611–2203 | | PVT-Constant Volume Capsule with null-type diaphragm | | Achener et al. (1967) | 16 |

Table 4 (Continued)

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $\frac{P\tilde{V}}{RT} = 1 + \frac{B}{\tilde{V}} + \frac{C}{\tilde{V}^2} + \frac{D}{\tilde{V}^3}$<br>$\log_{10} \lvert B \rvert = -3.8787 + \frac{4890.7}{T} + \log_{10} T;\ B < 0$<br>$\log C = 0.587\ e + \frac{6385.7}{T}\ ;\ C > 0$<br>$\log \lvert D \rvert = 1.4595 + \frac{7863.8}{T}\ ;\ D < 0$<br>[P = atm; T = °R; V = $ft^3$/lb-mole] | (3) | 1600–2500 | | PVT-Closed Chamber with flexible diaphragm as null indicator | Virial coefficients derived graphically | Ewing et al. (1965) | 14 |
| $P\tilde{V} = RT + BP + CP^2 + DP^3$<br>$B = -(7.22185 \times 10^{-5})(10^{2943.72/T})(T^{1.1330})$<br>$C = -(2.55216 \times 10^{-9})(10^{5887.44/T})(T^{1.26660})$<br>$D = +(2.41943 \times 10^{-12})(10^{8831.16/T})(T^{1.39990})$<br>[P = atm; T = °K; V = $cm^3$/g-mole] | (4) | | | Calculated | Based on hard-sphere potential model, Davies second virial coefficients, and fit to Ewing et al. PVT data | Heimel (1967) | 17 |
| $PV = RT + JB'P$<br>$B' = b/T^m$<br>$b = -4.293 \times 10^{20}$ cal·°$K^6$/atm·g-atom<br>$m = 6$<br>[P = atm; T = °K; B′ = $cm^3$/g-atom]<br>[J = 41.305 $cm^3$·atm/cal; R = 82.06 $cm^3$/g-atom·°K] | (5) | 536–2340 | | Calculated | Empirical fit of low-temperature vapor pressure data to obtain constant b and integer m in relation defining B′ | Hicks (1963) | 19 |

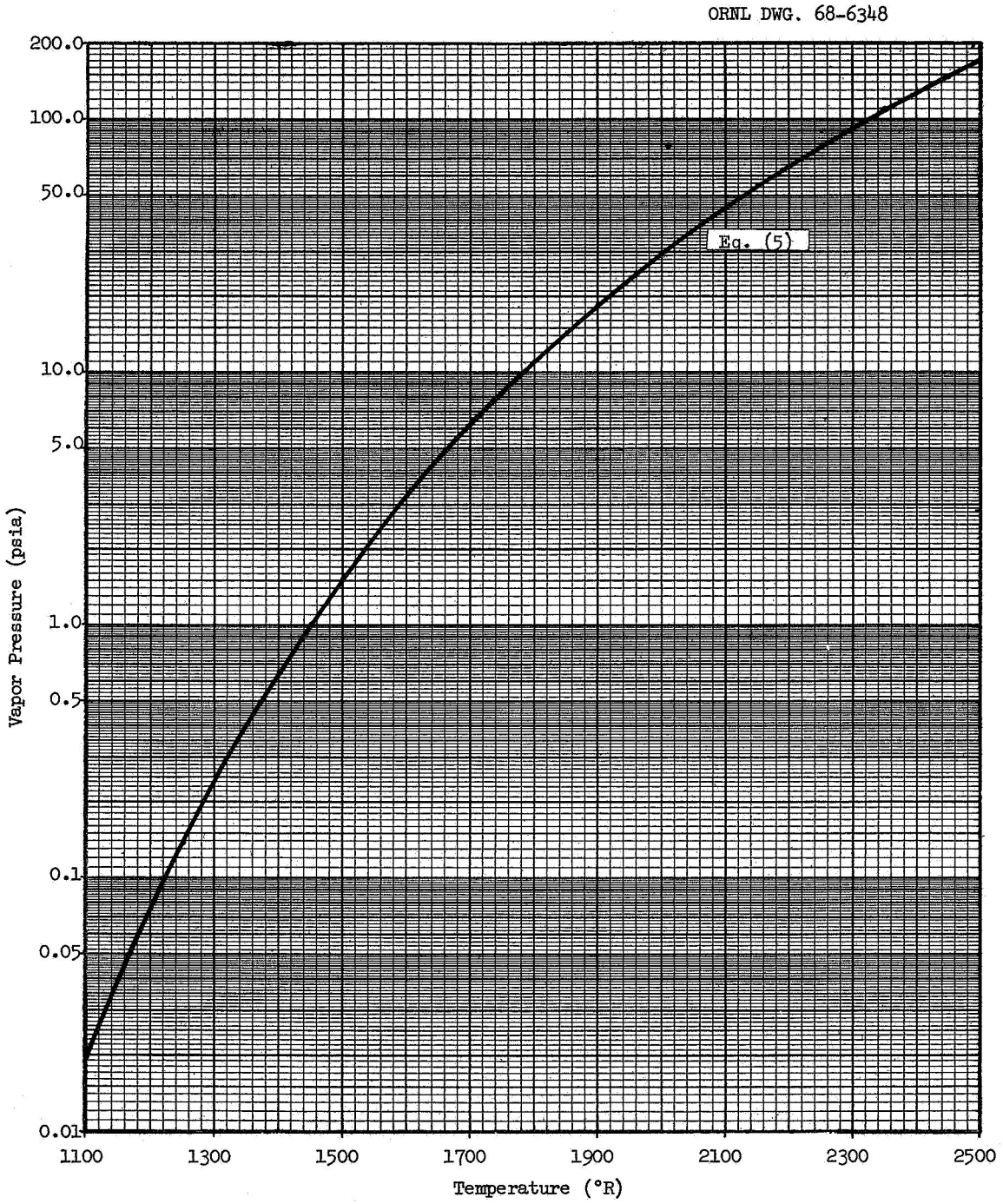


Fig. 2. Potassium: Vapor Pressure.

Table 5. Vapor Pressure

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $\log_{10} P = -\frac{4794.3}{T} - 1.97108 \log_{10} T + 4.9000 \times 10^{-4}\, T - 1.0659 \times 10^{-7}\, T^2 + 10.1451 + \frac{1915.4}{T} e^{-4338.9/T} + \frac{7.40 \times 10^4}{T} e^{-1.056 \times 10^4/T}$ [P = atm; T = °K] | (1) | 903–2115 | ±0.0097 in $\log_{10} P$ | Boiling | Function representation from third law treatment; uncertain corrections to raw data | Lemmon et al. (1963) | 15 |
| $\log_{10} P = 4.185 - \frac{4332}{T}$ [P = atm; T = °K] | (2) | 903–2115 | See Comments | Boiling | A simpler expression with following relation to Eq. (1): at 950°F, the same; 1160°F, ~0.5% low; 1520°F, ~0.5% low; 1700°F, ~1.5% low; 1880°F, ~1.5% low; 2060°F, ~2.0% low | Lemmon et al. (1963) | 15 |
| $\log_{10} P = 4.94758 - 0.22226 \log_{10} T - \frac{4421.94}{T}$ [P = atm; T = °K] | (3) | 1458–2241 | ±0.6% in P | Vapor Pressure Apparatus | | Rigney et al. (1965) | 21 |
| $\log_{10} P = 5.31574 - \frac{7707.31}{T + 459.7}$ [P = psia; T = °F] | (4) | 985–1909 | ±0.65% in P | Flow Calorimeter | | Achener et al. (1965) | 16,22 |

Table 5 (Continued)

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $\log_{10} P = 6.12758 - 0.53299 \log_{10} T - \frac{8128.77}{T}$ [P = atm; T = °R] | (5) | 1417–2393 | ±0.31% in P | Null Point | One of two equations obtained; this equation recommended and used in computing other thermodynamic properties | Ewing et al. (1965) | 14 |
| $\log_{10} P = 6.0398 - 0.5 \log_{10} T - \frac{8193.6}{T}$ [P = atm; T = °R] | (6) | <1400 | | Calculated | Derived from data of 12 previous investigations | Ditchburn & Gilmour (1941) | 20 |
| $\log_{10} P = -\frac{4207}{T} + 4.096$ [P = atm; T = °K] | (7) | 1089–1846 | ±1.1% in P | Boiling | | Makansi et al. (1956) | 24 |
| $\log_{10} P = 6.59817 - 0.700643 \log_{10} T - \frac{4625.3}{T}$ [P = atm; T = °K] | (8) | 210–3280 | ±1.43% in P | Calculated | Developed by least-squares fit of 7 sets of data; yields normal boiling point = 1396.0°F | Heimel (1967) | 17 |
| $\log_{10} P = 7.56 - 4587/T$ [P = torr; T = °K] | (9) | 150–255 | | Effusion | | Buck & Pauly (1965) | 53 |
| $\log_{10} P = -\frac{4507}{T} + 7.3447$ [P = mm Hg; T = °C] | (10) | 212–392 | | Effusion | | Edmondson & Egerton (1927) | 29 |
| $\log_{10} P = 6.160 - 0.5 \log_{10} T - \frac{4970}{T}$ [P = atm; T = °K] | (11) | 1022–2336 | 2% | Boiling | Used a specially designed compensating pressure gage | Grachev & Kirilov (1960) | 23 |

Table 5 (Continued)

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $\log_{10} P = -\frac{4802.22}{T} - 1.97108 \log_{10} T + 4.9800 \times 10^{-4}\ T - 1.0659 \times 10^{-7}\ T^2 + 10.14506 + \frac{1915.4}{T} e^{-4338.9/T}$ [P = atm; T = °K] | (12) | to 1700 | | Calculated | Imperfect gas treatment assuming inclusion of second virial coefficient to be adequate; uses unpublished data of Johnson et al. and of Makansi et al. | Thorn & Winslow (1961) | 25 |
| $\log_{10} P = 4.127 - \frac{4243.4}{T}$ [P = atm; T = °K] | (13) | 1089–1846 | | Calculated | Data of Makansi reevaluated by Thorn & Winslow weighting log P with $P^2$. Constant is 4.127 rather than 4.927 shown in paper. | | 25 |

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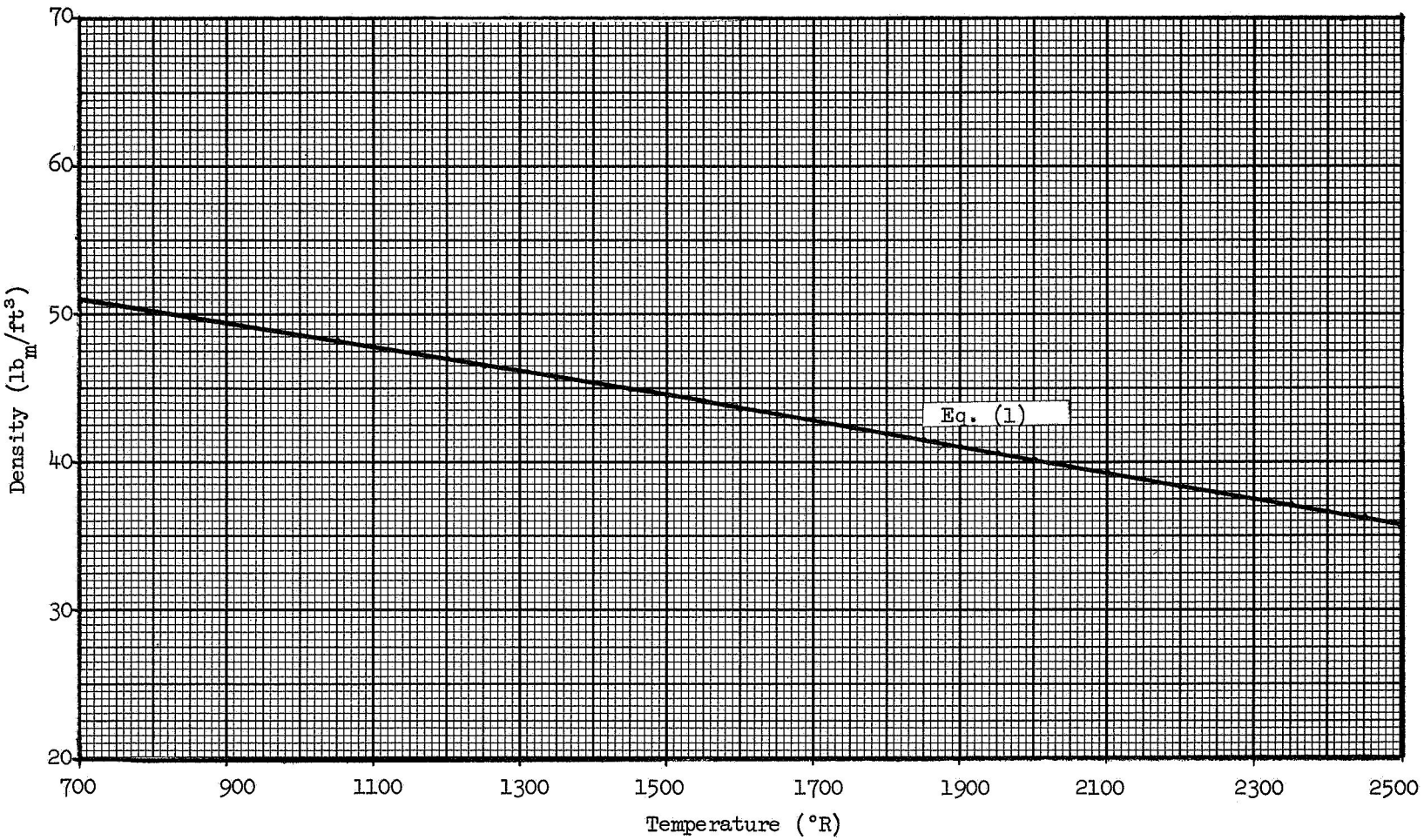


Fig. 3. Potassium: Liquid Density.

Table 6. Liquid Density

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $\rho = 52.768 - 7.4975 \times 10^{-3}T - 0.5255 \times 10^{-6}T^2 + 0.0498 \times 10^{-9}T^3$ [$\rho = lb_m/ft^3$; T = °F] | (1) | mp − 2300 | ±0.4% | Calculated | Best fit to combined data of 6 investigations, Ewing measurements made with pychometer. | Ewing et al. (1965) | 14 |
| $\rho = 0.83162 - 0.97185 \times 10^{-4}T - 0.15435 \times 10^{-7}T^2 + 0.14358 \times 10^{-11}T^3$ [$\rho = g/cm^3$; T = °F] | (2) | 470-2000 | 0.0014 $g/cm^3$ | Dilatometer | Best fit of 3 equations fitted to experimental data. | Tepper et al. (1965) | 84 |
| $\rho = 0.84927 - 0.13004 \times 10^{-3}T$ [$\rho = g/cm^3$; T = °F] | (3) | 470-2000 | 0.0041 $g/cm^3$ | Dilatometer | "Probably adequate for most applications." Eq. (2) above apparently much more accurate for T >1400°F. | Tepper et al. (1965) | 84 |
| $\rho = 0.826 - 0.000222\ (T - 62.4)$ [$\rho = g/cm^3$; T = °C] | (4) | mp − 1200 | ±0.002 $g/cm^3$ | Buoyancy | | Rinck (1929) | 38 |
| T / ρ: 100 818; 150 807; 200 795; 250 784; 300 773; 350 761; 400 750; T / ρ: 450 738; 500 727; 550 716; 600 704; 650 692; 700 681 [$\rho = Kg/m^3$; T = °C] | (5) | mp − 1350 | ~0.4% | Pycnometer | Investigator shows results in form of a graph; values tabulated are as listed by Kutateladze et al. (Ref. ) | Novikov et al (1956) | 37 |

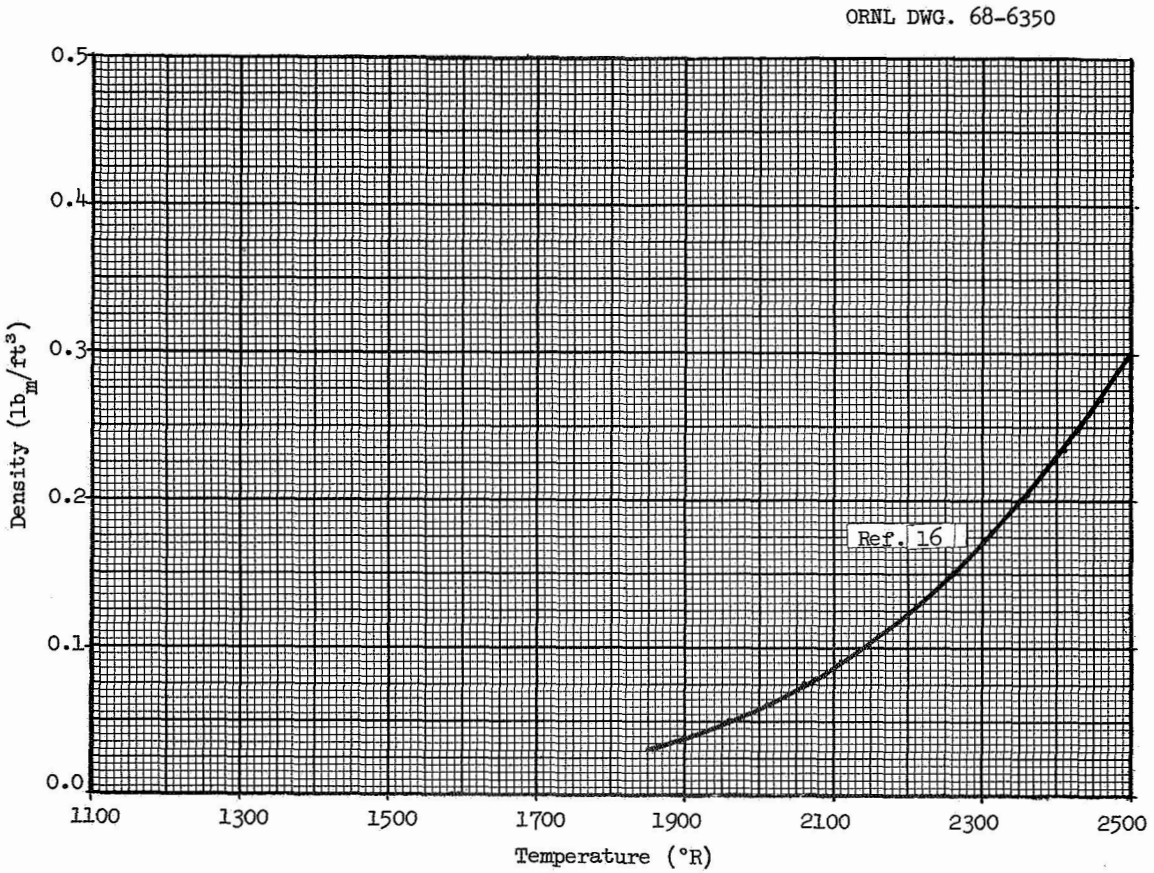


Fig. 4. Potassium: Saturated Vapor Density.

Table 7. Liquid Compressibility

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comment | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| Adiabatic: $K_S = 36.2 \times 10^{-6}$ bar$^{-1}$<br>Isothermal: $K_T = 40.2 \times 10^{-6}$ bar$^{-1}$<br>[1 bar = 0.98692 atm] | | 147 | | Calculated | Obtained by calculation from measured sonic velocity. | Kleppa (1950) | 10 |

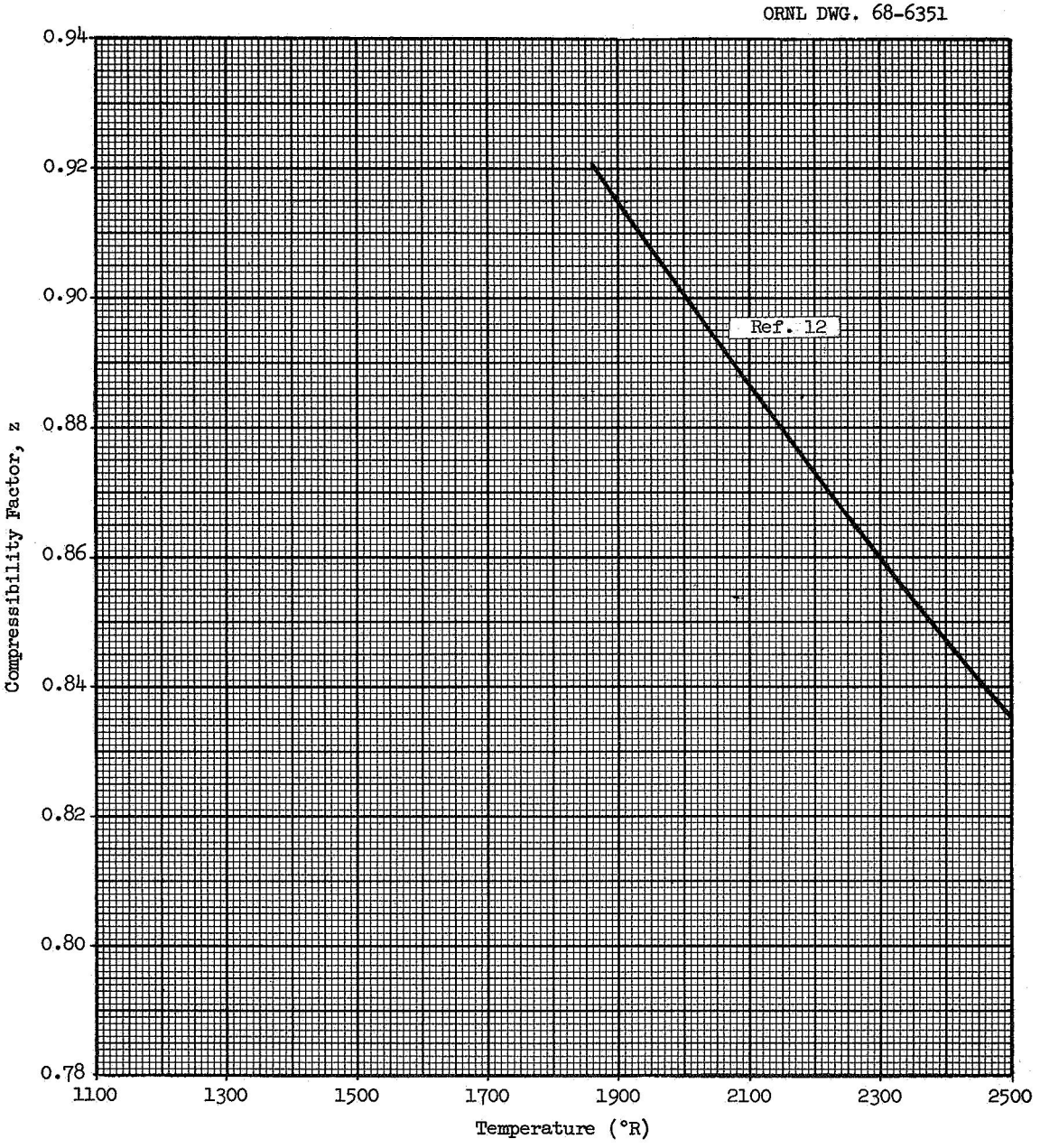


Fig. 5. Potassium: Saturated Vapor Compressibility.

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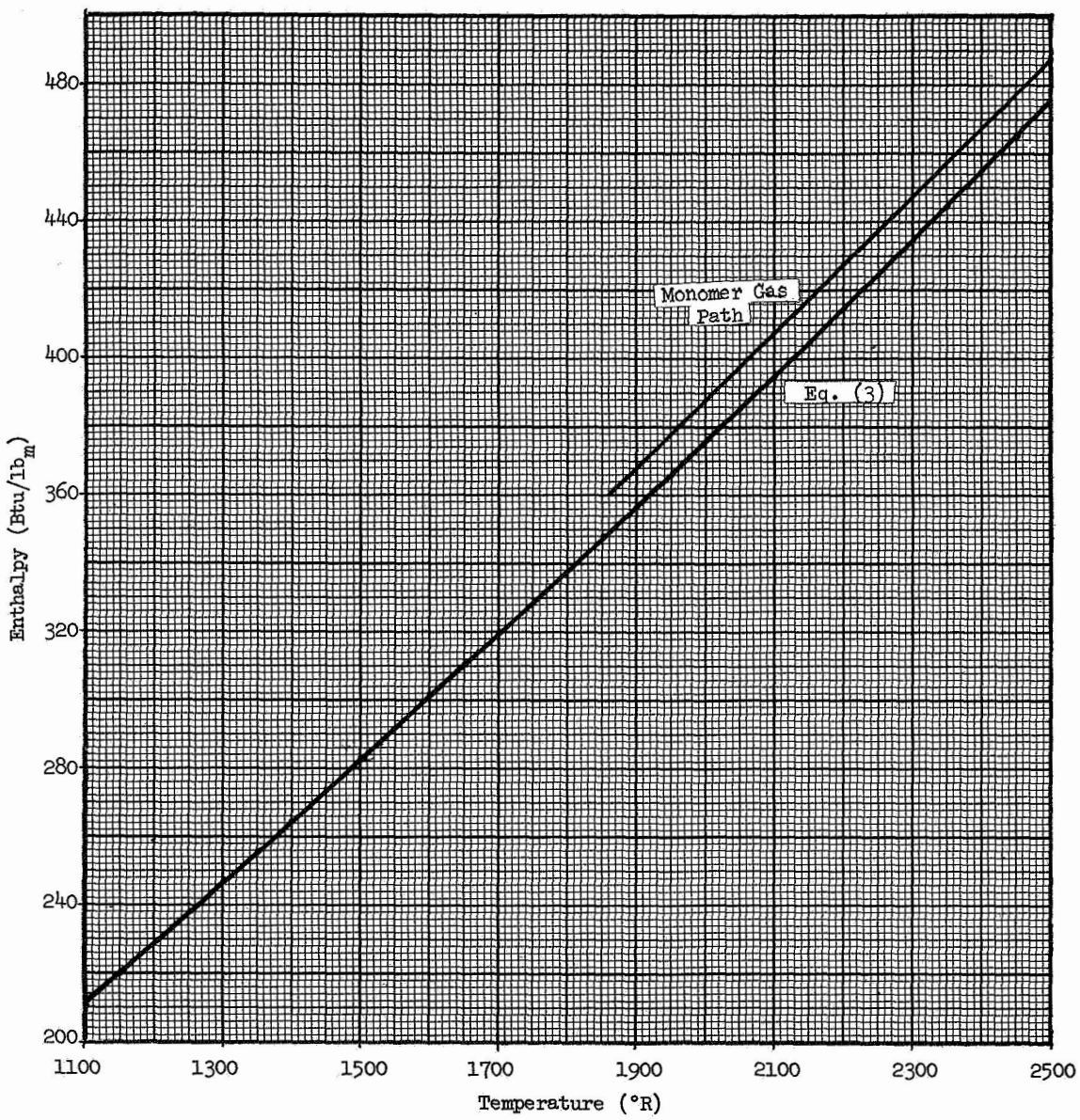


Fig. 6. Potassium: Liquid Enthalpy.

Table 8. Liquid Enthalpy

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $H_T = 13.453 + 0.20070T - 0.45421 \times 10^{-4}T^2 + 0.38019 \times 10^{-2}T^7$ [H = cal/g; T = °C] | (1) | 145-2102 | 1.69 cal/g | Calorimeter | Corrected for oxide formation on capsule and internal vapor condensation; greater accuracy for T < 1772°F. | Lemmon et al. (1963) | 15 |
| $H_T - H_o = 56.179 + 0.840741T - 1.58440 \times 10^{-4}T^2 + 1.04993 \times 10^{-7}T^3$ [H = joule/g; T = °C] | (2) | 145-1472 | ±0.3% for T >392°F | Calorimeter | Relative to solid at 0°C | Douglas et al. (1952) | 40 |
| $H_T - H_o = 87.8783 + 0.2022T - 0.2177 \times 10^{-4}T^2 + 0.07741 \times 10^{-7}T^3$ [H = Btu/$lb_m$; T = °F] | (3) | <2200 | | Calculated | Relative to solid at 0°R; derived from specific heat equations of Douglas et al. for solid and liquid K over range 32 to 1472°F. | Ewing et al. (1965) | 14 |

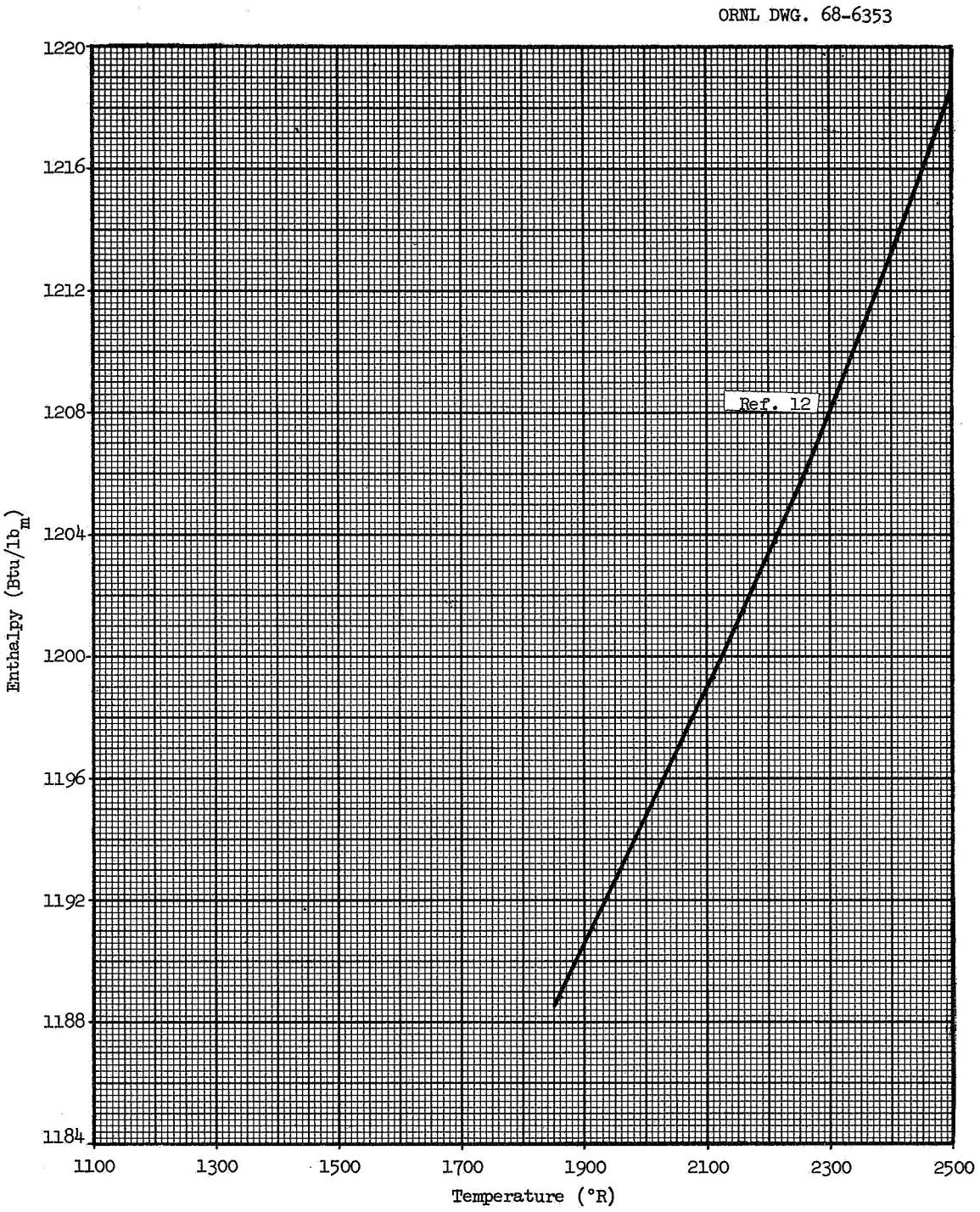


Fig. 7. Potassium: Saturated Vapor Enthalpy.

Table 9. Saturated Vapor Enthalpy

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $H_{sat} - H_{298} = 4.801\ T - 2.285 \times 10^{-3}T^2 + 9.812 \times 10^{-7}T^3 + 1.9734 \times 10^4$<br>[H = cal/mole; T = °K] | (1) | 1150–2275 | | Thermodynamic calculation | From PVT data | Achener et al. (1967) | 16 |
| T / $H_T$: 1400 / 1188.81; 1500 / 1193.06; 1600 / 1197.23; 1700 / 1201.52; 1800 / 1206.11; 1900 / 1211.09; 2000 / 1216.45<br>[H = Btu/lb$_m$; T = °F] | (2) | | | Thermodynamic calculation | From PVT data; listed values extracted from Appendix A of Ref. 16 | Ewing et al. (1965) | 14 |
| T / $H_T/RT$: 400 / 25.5744; 600 / 19.1141; 800 / 14.7435; 1000 / 12.0196; 1200 / 10.1509; 1400 / 8.7973; 1600 / 7.7840<br>[H = cal/mole; T = °K]<br>[R = gas constant = 1.98717 cal/mole·°K] | (3) | | | Thermodynamic calculation | Used experimental data of others; listed values extracted from Table VIII of Ref. 33 | Heimel (1967) | 17 |
| T / $H_g - H_o$: 1400 / 1164.0; 1500 / 1171.2; 1600 / 1177.1; 1700 / 1182.0; 1800 / 1185.7; 1900 / 1188.1; 2000 / 1188.8; 2100 / 1187.6; 2200 / 1183.8; 2300 / 1176.6; 2400 / 1165.1; 2500 / 1148.0<br>[H = Btu/lb$_m$; T = °R] | (4) | | | Thermodynamic calculation | Used BMI experimental data; values abstracted from Table A-1, Ref. 38 | Lemmon et al. (1963) | 15 |

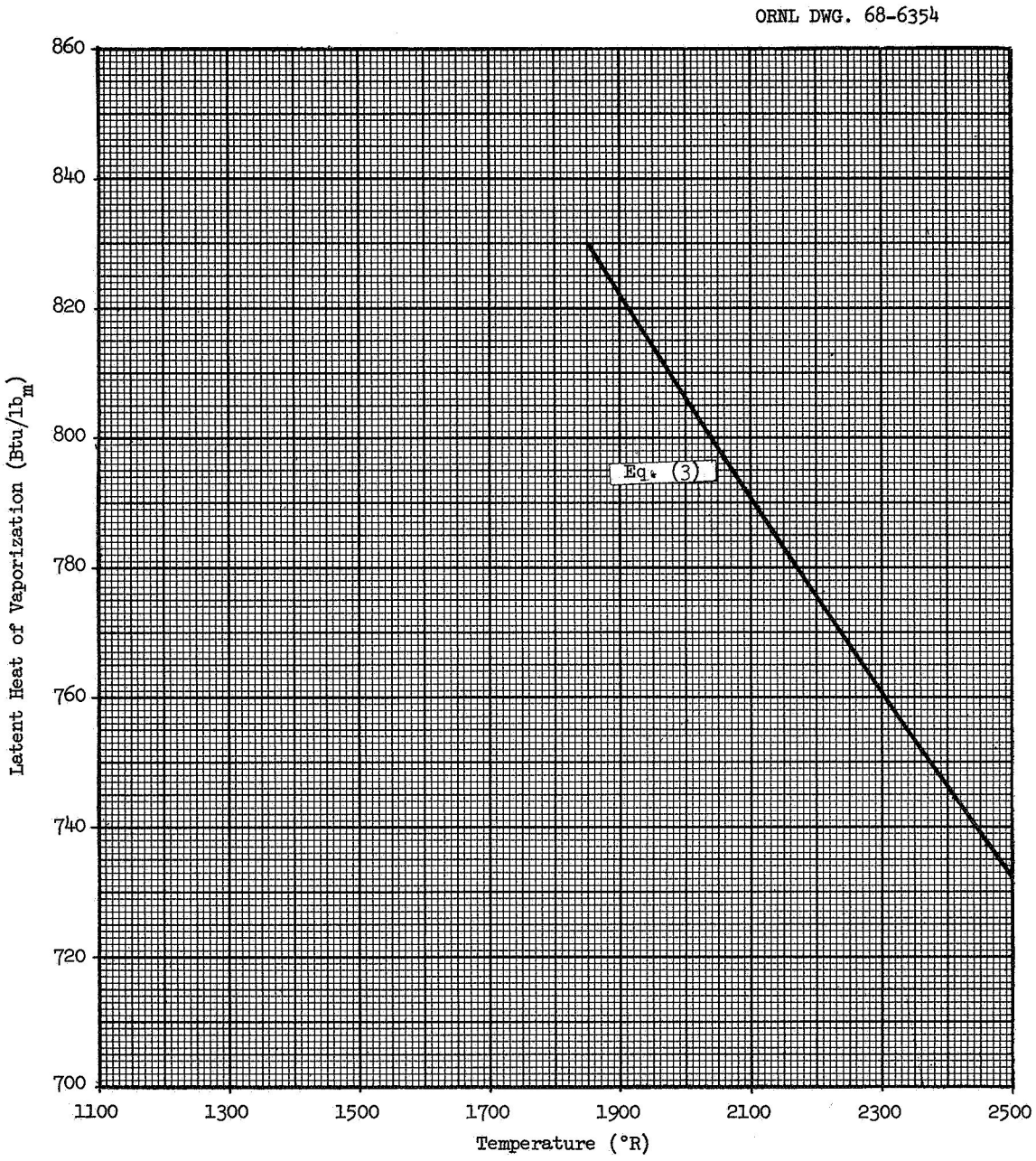


Fig. 8. Potassium: Latent Heat of Vaporization.

Table 10. Latent Heat of Vaporization

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $h_{fg} = 2.7203\ P_{sat}\left(\frac{17822.5}{T_{sat}} - 0.002136\right)\left[\frac{RT_{sat}}{M_1 P_{sat}} - 10^{(4080/T_{sat} - 1.803)} - \frac{0.016091}{0.844 - 2.42 \times 10^{-4}\ \frac{(T_{sat} - 491.7)}{1.8}}\right]$ [$h_{fg}$ = Btu/lb$_m$; $P_{sat}$ = atm; $T_{sat}$ = °R; $M_1$ = monomer atomic weight = 39.1] | (1) | | ±90 cal | Clausius-Clapeyron Calculation | Derived using investigators' vapor pressure expression and volume relationships of Ewing and of Hall & Blocher | Rigney et al. (1965) | 21 |
| $h_{fg} = 948.5 - 0.1044\ T$ [$h_{fg}$ = Btu/lb$_m$; T = °F] | (2) | 1008–1907 | ±0.8% | Flow Calorimeter | Investigator claims a much higher accuracy for data than for values derived via Clausius-Clapeyron equation | Achener et al. (1965) | 22 |
| $h_{fg} = JP_{sat}\left[\frac{18,717}{T_{sat}} - 0.53299\right][V_g - V_\ell]$ [$h_{fg}$ = Btu/lb$_m$; $P_{sat}$ = atm; $T_{sat}$ = °R; V = ft$^3$/lb$_m$] | (3) | | | Clausius-Clapeyron calculation | $\frac{dP}{dT}$, $V_g$, $V_\ell$ from NRL measurements | Ewing et al. (1965) | 14 |

Table 10 (Continued)

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $T$ / $h_{fg}$<br>1300 / 910<br>1500 / 888<br>1700 / 861<br>1900 / 828<br>2100 / 787<br>2300 / 733<br>[$T$ = °R; $h_{fg}$ = Btu/lb$_m$] | (4) | 840–2140 | ±5 Btu/lb$_m$ | Clausius-Clapeyron Calculation | | Lemmon et al. (1963) | 15 |
| $T$ / $h_{fg}/RT$<br>400 / 25.905<br>600 / 16.769<br>800 / 12.087<br>1000 / 9.173<br>1200 / 7.155<br>1400 / 5.661<br>1600 / 4.495<br>[$T$ = °K; $h_{fg}$ = cal/mole]<br>[$R$ = 1.98717 cal/mole·°K] | (5) | | | Calculated | Enthalpy change on equilibrium vaporization of 1 mole of real monomer at T °K | Heimel (1967) | 17 |

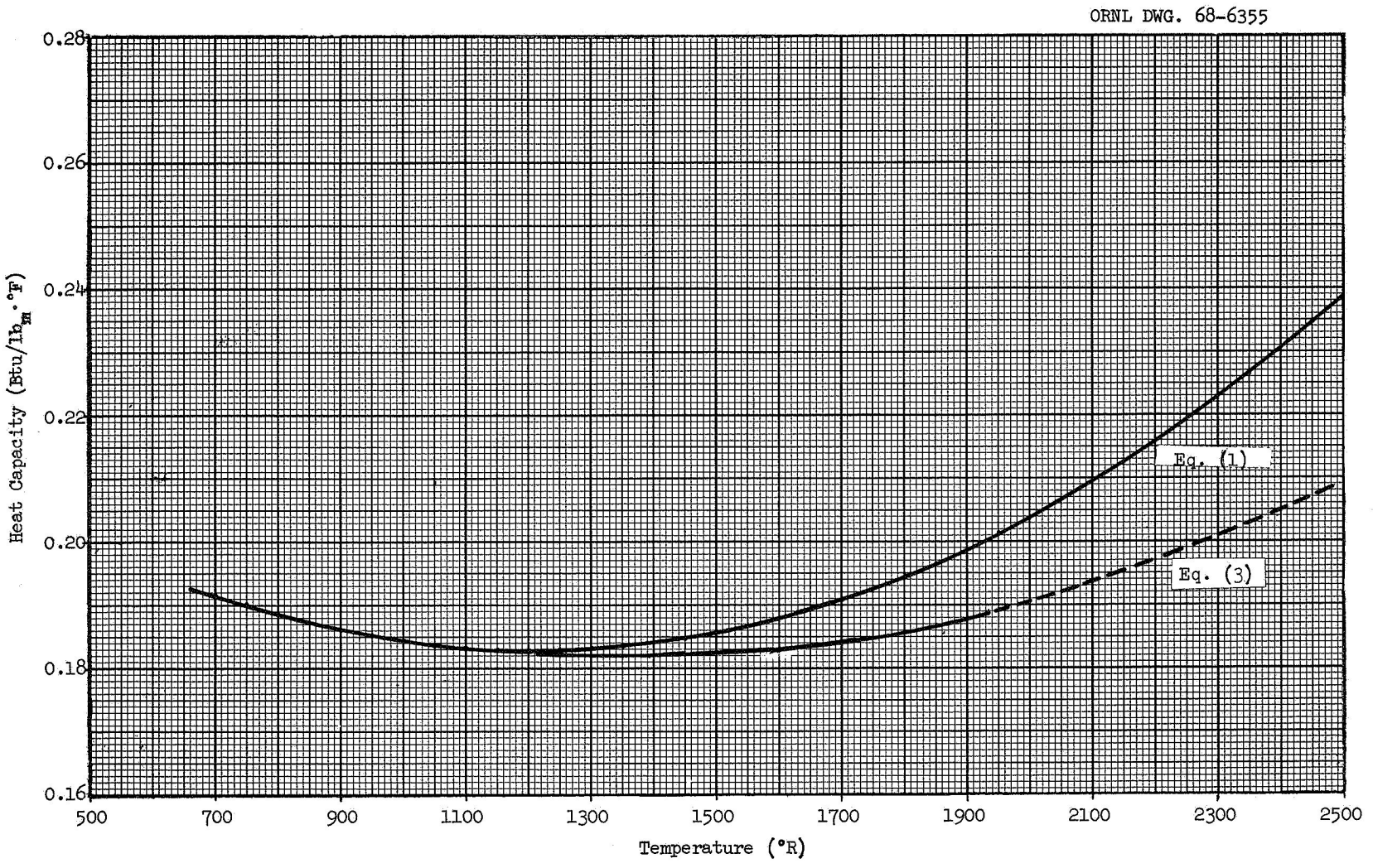


Fig. 9. Potassium: Liquid Heat Capacity.

Table 11. Liquid Heat Capacity

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $C_p = 0.2004 - 0.8777 \times 10^{-4}T + 1.0970 \times 10^{-7}T^2$<br>[$C_p$ = cal/g·°C; T = °C] | (1) | 145–932<br>932–2102 | ±2%<br>±5% | Derived | Includes $V \frac{dp}{dt}$ correction | Lemmon et al. (1963) | 15 |
| T / $C_p$<br>100 / 0.195<br>150 / 0.192<br>200 / 0.189<br>250 / 0.187<br>300 / 0.185<br>350 / 0.184<br>400 / 0.183<br>[$C_p$ = cal/g·°C; T = °C] | (2) | 257–752 | | Derived | Values from average curve fitted to data | Nikol'skii et al. | 46 |
| $C_p = 0.84074 - 3.1688 \times 10^{-4}T + 3.1435 \times 10^{-7}T^2$<br>[$C_p$ = joule/g·°C; T = °C] | (3) | 145–1472 | ±0.4%<br>100°C < T<br><700°C | Derived | Includes $V \frac{dp}{dt}$ correction;<br>$V \frac{dp}{dt} = 6.27 \times 10^{-10}T^2$ | Douglas et al. (1952) | 40 |

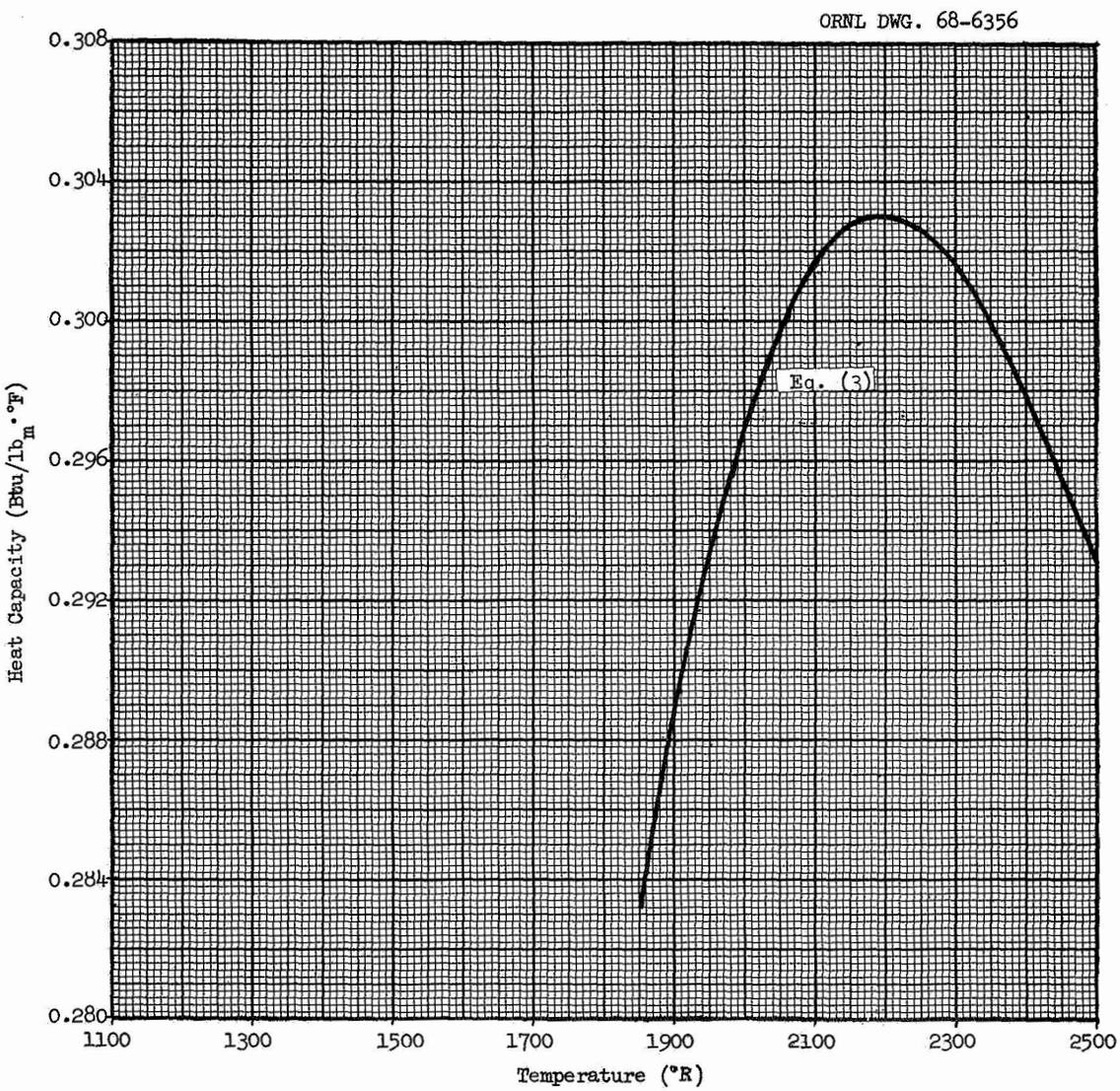


Fig. 10. Potassium: Saturated Vapor Heat Capacity.

Table 12. Saturated Vapor Heat Capacity

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| T / $C_p$<br>1300 / 0.1681<br>1500 / 0.2059<br>1700 / 0.2539<br>1900 / 0.3113<br>2100 / 0.3788<br>2300 / 0.4585<br>2500 / 0.5534<br>[T = °R; $C_p$ = Btu/$lb_m$·°R] | (1) | | | Calculated | | Lemmon et al. (1963) | 15 |
| T / $C_p$<br>1400 / 0.2842<br>1600 / 0.3001<br>1800 / 0.3024<br>2000 / 0.2950<br>2200 / 0.2883<br>[T = °F; $C_p$ = Btu/$lb_m$·°F] | (2) | | | Calculated | Numerical evaluation of<br>$(C_p)_s = \left[\left(\frac{\Delta h}{\Delta T}\right)_p\right]_s$<br>using virial (monomer gas path) equation for enthalpy | Ewing et al. (1965) | 14 |
| T / $C_p$<br>336.35 / 5.012<br>500 / 5.627<br>800 / 8.679<br>900 / 9.748<br>1000 / 10.671<br>1500 / 12.311<br>2000 / 10.683<br>[T = °K; $C_p$ = cal/mole·°K] | (3) | | | Calculated | Based on hard-sphere potential model | Heimel (1967) | 17 |
| T / $C_p$<br>1200 / 0.2440<br>1400 / 0.2572<br>1600 / 0.2765<br>1800 / 0.3298<br>2000 / 0.3821<br>[T = °F; $C_p$ = Btu/$lb_m$·°F] | (4) | | | Calculated | Calculated from a base of 0.0002 atm | Achener et al. (1967) | 16 |

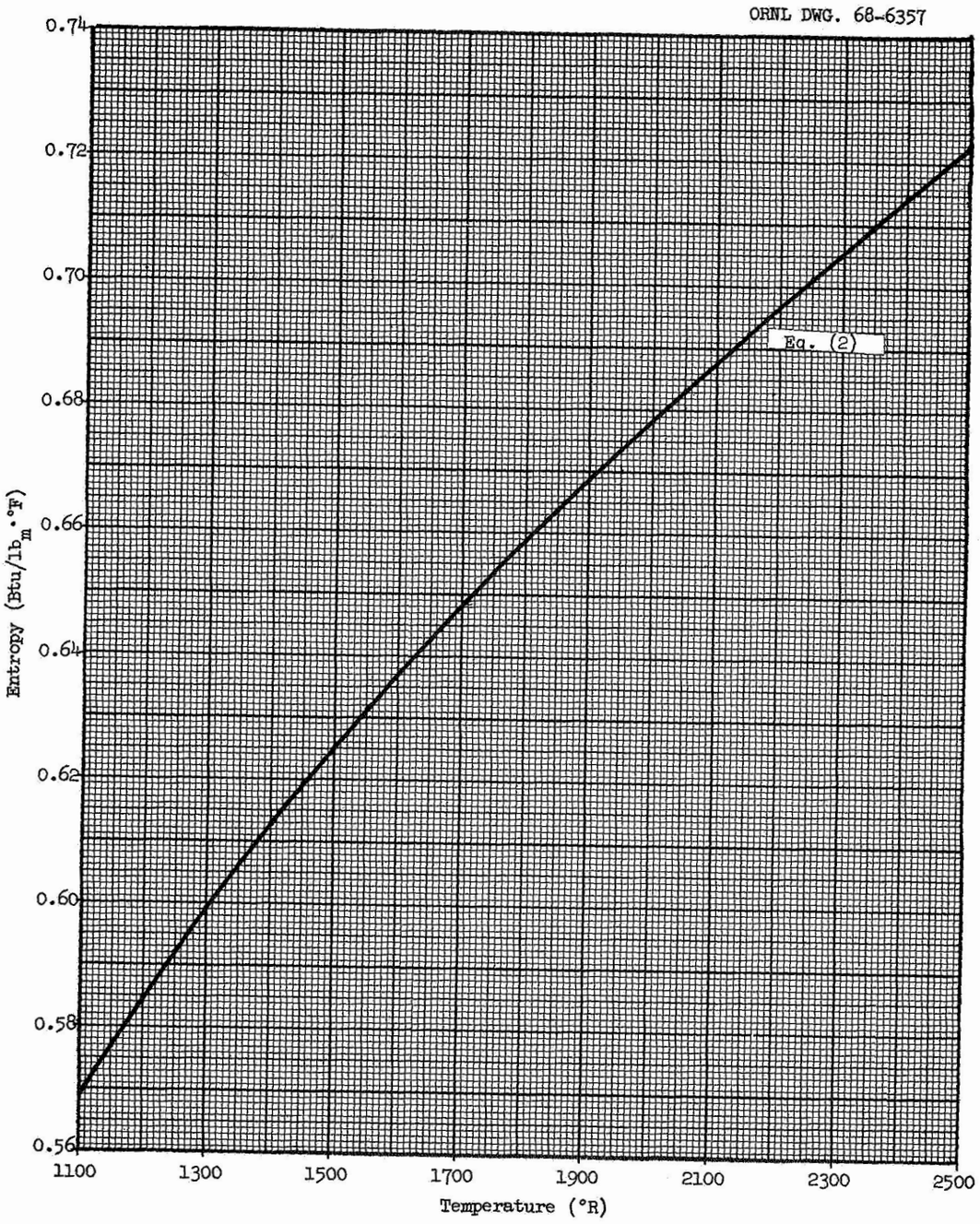


Fig. 11. Potassium: Liquid Entropy.

Table 13. Liquid Entropy

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigation (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $S_T - S_{273} = -5.04665 + 2.18919 \log_{10} T - 4.8862 \times 10^{-4}T + 1.5718 \times 10^{-7}T^2$ [S = joule/g·°K; T = °K] | (1) | 145–1472 | | Calculated | Based on investigators enthalpy equation | Douglas et al. (1952) | 40 |
| $S_T - S_o = -0.9646 + 0.52298 \log_{10} T - 0.64848 \times 10^{-4}T + 0.11589 \times 10^{-7}T^2$ [S = Btu/$lb_m$·°F; T = °R] | (2) | <2200 | | Calculated | Based on Dougles et al.; extrapolates $C_p$ data to high temperatures | Ewing et al. (1965) | 14 |
| T / $S_T$: 1200 / 0.5838; 1400 / 0.6120; 1600 / 0.6368; 1800 / 0.6593; 2000 / 0.6802; 2200 / 0.7002; 2400 / 0.7196; 2600 / 0.7387 [$S_T$ = Btu/$lb_m$·°R; T = °R] | (3) | | | Calculated | Based on experimenters enthalpy measurements | Lemmon et al. (1963) | 15 |

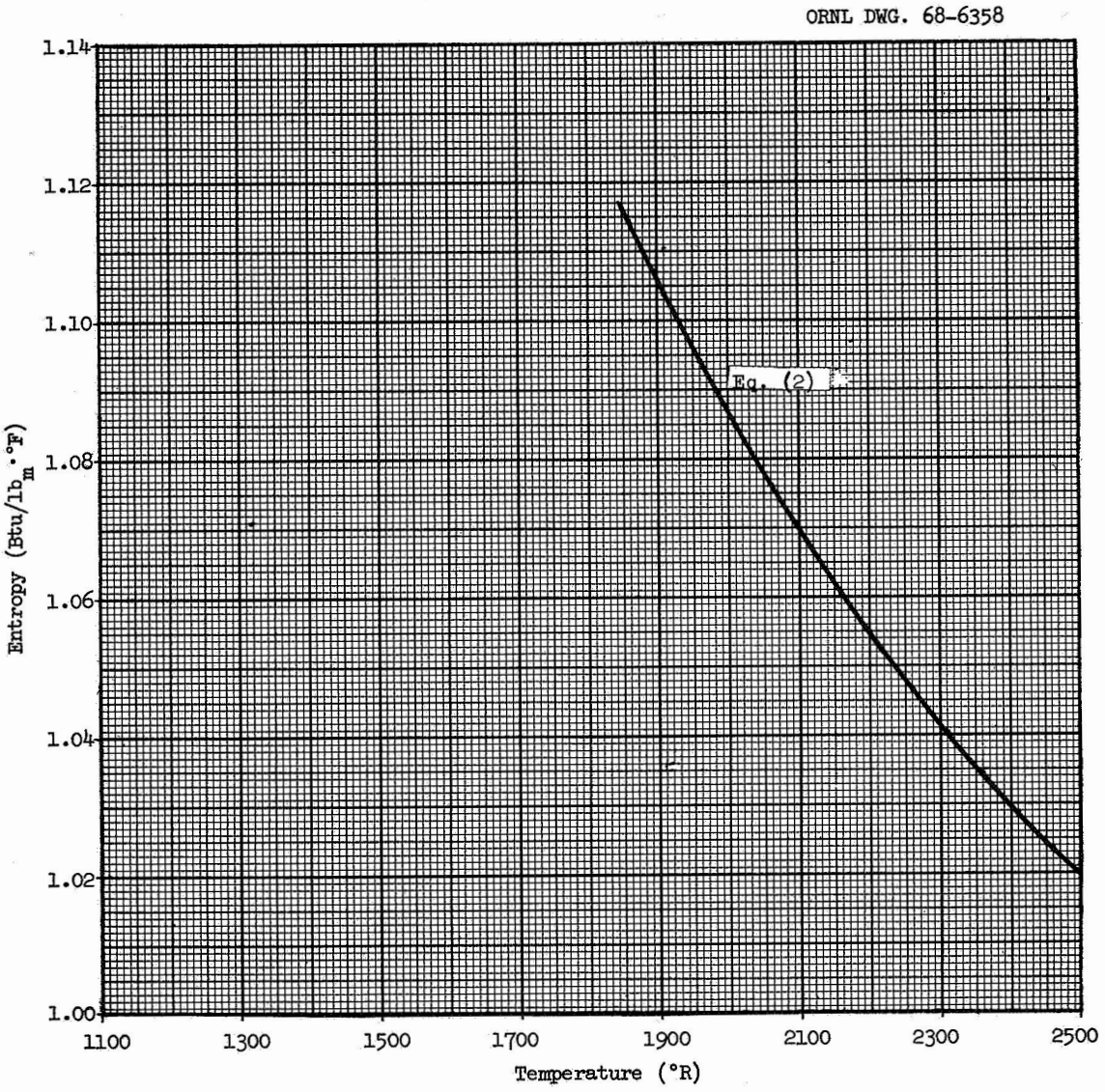


Fig. 12. Potassium: Saturated Vapor Entropy.

Table 14. Saturated Vapor Entropy

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date | Refs. |
|---|---|---|---|---|---|---|---|
| $S_{sat} - S_{298} = -36.385 + (2.166 \times 10^4)/T + 20.461 \log_{10} T - 4.57 \times 10^{-3}T + 1.4718 \times 10^{-6}T^2$<br>[S = cal/mole·°K; T = °K] | (1) | 1150–2275 | | Thermodynamic calculation | From PVT data | Achener et al. (1967) | 16 |
| T / $S_T$: 1400 / 1.1143; 1500 / 1.0940; 1600 / 1.0761; 1700 / 1.0604<br>T / $S_T$: 1800 / 1.0466; 1900 / 1.0344; 2000 / 1.0237<br>[S = Btu/$lb_m$·°F; T = °F] | (2) | | | Thermodynamic calculation | From PVT data; listed values from Appendix A, Ref. 14 | Ewing et al. (1965) | 14 |
| T / $S_T/R$: 400 / 27.5744; 600 / 19.1141; 800 / 14.7435; 1000 / 12.0196<br>T / $S_T/R$: 1200 / 10.1504; 1400 / 8.7973; 1600 / 7.7840<br>[$S_T$ = cal/mole·°K; T = °K]<br>[R = gas constant = 1.98717 cal/mole·°K] | (3) | | | Thermodynamic calculation | Used experimental data of others; listed values from Table VIII, Ref. 17 | Heimel (1967) | 17 |
| T / $S_T$: 1400 / 1.2544; 1500 / 1.2168; 1600 / 1.1839; 1700 / 1.1549; 1800 / 1.1291; 1900 / 1.1059<br>T / $S_T$: 2000 / 1.0847; 2100 / 1.0651; 2200 / 1.0465; 2300 / 1.0285; 2400 / 1.0106; 2500 / 0.9922<br>[$S_T$ = Btu/$lb_m$·°R; T = °R] | (4) | | | Thermodynamic calculation | Values from Table A-1, Ref. 15 | Lemmon et al. (1963) | 15 |

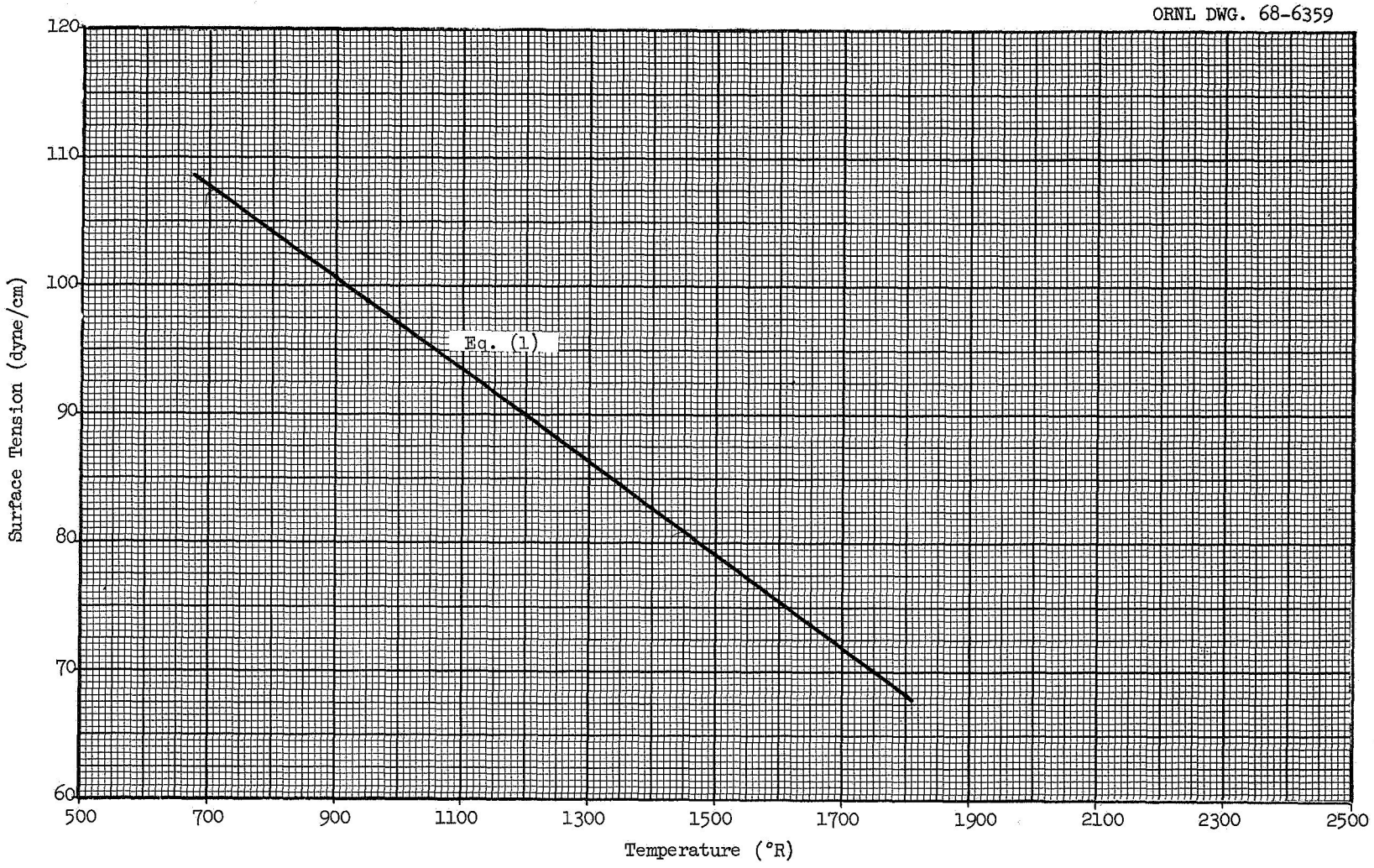


Fig. 13. Potassium: Liquid Surface Tension.

Table 15. Surface Tension

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $\sigma = 115.36 - 0.0646T$ [$\sigma$ = dyne/cm; T = °C] | (1) | 158-1315 | ±0.72 dyne/cm | Maximum bubble pressure | Used Raleigh-Schroedinger equation to calculate $\sigma$ | Cooke (1964) | 49 |
| $\sigma = 86 \rightarrow 95$ erg/cm$^3$ | (2) | 148 –302 | | Capillary rise | | Quarterman and Primak (1950) | 50 |
| $\sigma = 101 - 0.11\ (T - 70)$ [$\sigma$ = erg/cm$^2$; T = °C] | (3) | 158-968 | | Maximum bubble pressure | Used Sugden's method of correction for bubble distortion | Taylor (1955) | 51,52 |
| $\sigma = 102.1 - 0.06\ T$ [$\sigma$ = dyne/cm; T = °C] | (4) | mp to 400 | ±1.0 dyne/cm | Vertical-plate balance | Measured with Ag and Zn plates | Jordan & Lane (1965) | 90 |

# TRANSPORT PROPERTIES

## Introduction

The transport properties characterize a material with respect to the molecular processes of momentum, heat, and mass exchange. Viscosity, thermal conductivity, thermal diffusivity, thermal diffusion ratio, and mass diffusivity fall within this category. The electrical resistivity is also included in this section, since measurements of this property are often used (through the Wiedemann-Franz-Lorenz relationship) to calculate the thermal conductivity.

## Viscosity

The viscosity, $\mu$, characterizes the flow resistance of simple fluids and appears as the proportionality coefficient in Newton's law of viscosity:

$$\tau_{yx} = -\mu \frac{dv_x}{dy} ,$$

which states that the shear force per unit area is proportional to the negative of the local velocity gradient normal to the mean flow. The negative sign* specifies that the viscous (molecular) momentum flux tends to go in the direction of decreasing velocity. This also enables a treatment which is consistent with that commonly employed for energy (heat) and mass transport.

### Liquid Viscosity

The results of five experimental measurements of the viscosity of liquid potassium are given in Table 16; an extrapolation of existing data to very high temperatures (3950°F) by Grosse[73] and a corresponding

*R. B. Bird, W. E. Stewart, and E. N. Lightfoot, Transport Phenomena, p. 5, John Wiley & Sons, New York – London, 1960.

states prediction (Appendix A) by Chapman[74] are also shown. Only Lemmon et al.[15] [Table 16, Eq. (1)] and Shpil'rain et al.[75] [Table 16, Eq. (2)] give experimental results for temperatures above 1300°F. These two data sets compare as follows:

| Temperature (°R) | Viscosity ($lb_m$/hr·ft) Lemmon (I) | Shpil'rain (II) | Difference (%) (II–I)/I |
|---|---|---|---|
| 700 | 1.074 | 1.043 | -2.9 |
| 1050 | 0.609 | 0.594 | -2.5 |
| 1400 | 0.425 | 0.425 | 0.0 |
| 1750 | 0.334 | 0.338 | +1.2 |
| 2100 | 0.284 | 0.284 | 0.0 |
| 2450 | 0.253 | 0.247 | -2.4 |

Of the lower temperature results, Chiong[76] and Novikov[37] agree well with Lemmon (~5%); Ewing et al.[77] results fall about 10% below Lemmon.

Grosse[73,78] estimated the absolute viscosity of potassium over the entire liquid range – i.e., from the melting to the critical temperature – using existing experimental data (Ewing and Lemmon) to 2100°F (1422°K) to obtain the constants in Andrade's second equation[79,80]

$$\mu V^{1/3} = A e^{C/VT} ,$$

where A and C are constants for a particular liquid; $\mu$, the absolute viscosity (poise); V, the specific volume ($cm^3/g$); and T, the temperature (°K). His values are shown as Eq. (4).

Chapman[74] presents a corresponding states prediction of the viscosity of liquid metals. Calculations for potassium, following the example shown

in Appendix A, show that agreement with Lemmon's measurements is reasonable; Ewing et al.[14] densities were used in this computation.

| Temperature (°R) | Viscosity ($lb_m$/hr·ft) | |
|---|---|---|
| | Lemmon | Chapman |
| 700 | 1.074 | 1.140 |
| 1400 | 0.425 | 0.455 |
| 2100 | 0.284 | 0.266 |

The results of Lemmon et al. are recommended and are presented in Fig. 14.

Vapor Viscosity

Values for the viscosity of saturated potassium vapor are given in Table 17.

Grosse[78] [Eq. (1)] states that metal vapors can be expected to behave as predicted by simple kinetic theory — at least in the low temperature range; thus,

$$\mu = 2.6693 \times 10^{-5} \sqrt{MT}/\sigma^2 \quad ,$$

where $\mu$ is the viscosity of saturated vapor (poise), M is the molecular weight (g/g-mole), T is the temperature (°K), and $\sigma$ is the atomic diameter (Å). Grosse used Pauling's diameter for the potassium atom, 4.374 Å. In the higher temperature range, near the critical region (reduced temperature above 0.85) where the vapor pressure is high, experimental evidence suggests that the viscosity increases directly with the temperature. The results presented are for dilute (low pressure) gas. While corrections

for dense gas can be made, these were found by Grosse to effect only an 8% increase in $\mu_{vap}$ for mercury and were neglected with respect to potassium.

Weatherford[13,81] estimated the saturated vapor viscosity using the theoretical relationship,

$$\mu = \frac{0.001667\ (M^2PV)^{1/2}}{[\sigma_o + 283/(M^2PV)^{1/2}]^2} ,$$

where $\mu$ is the viscosity ($lb_m/ft \cdot hr$); P, the pressure (psia); V, the vapor volume ($ft^3/lb_m$); M, the equilibrium molecular weight; and $\sigma_o$ the hard-core collision diameter (Å). The latter quantity was calculated from M and the freezing-point density.

The agreement between Grosse and Weatherford is not good; thus

| Temperature (°F) | Vapor Viscosity ($lb_m/hr \cdot ft$) | |
|---|---|---|
| | Grosse | Weatherford |
| 1100 | 0.0621 | 0.0427 |
| 1400 | 0.0679 | 0.0471 |
| 1700 | 0.0731 | 0.0512 |
| 2000 | 0.0779 | 0.0546 |

Grosse is recommended; results are presented in Fig. 15.

## Thermal Conductivity

The thermal conductivity, k, of a material is the proportionality coefficient appearing in Fourier's law of heat conduction:

$$q_y = -k \frac{dT}{dy} \quad ;$$

this is the one-dimensional form of the equation relating the heat flux to the temperature gradient. Again, the negative sign indicates that the energy (heat) flux is in the direction of decreasing temperature. For a stationary homogeneous medium (k uniform in all directions), an energy balance involving conduction along the Cartesian axes into and out of a control volume and heat storage but neglecting internal heat generation yields the more general equation:

$$\frac{\partial T}{\partial \tau} = \alpha \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial x^2} \right) \quad ,$$

where $\tau$ = time and $\alpha$ = thermal diffusivity $(k/\rho C_p)$. This latter quantity is often of importance and can be calculated from the given values for k, $\rho$, and $C_p$. The Prandtl modulus, $N_{Pr} = C_p\mu/k$ (the ratio of the diffusivity of momentum, $\nu = \mu/\rho$, to the diffusivity of heat, $\alpha$) is also important in thermal processes and can be calculated from the properties tabulated.

### Liquid Thermal Conductivity

Data on the thermal conductivity of liquid potassium are given in Table 18; the results of Lemmon et al.[15] given by Eq. (1) and plotted in Fig. 16 are recommended.

Experimental measurements using (1) steady-state, longitudinal heat flow were performed by Lemmon et al. and by Ewing et al.;[82] (2) successive

stationary states, by Nikol'skii et al.;[46] and (3) unsteady-state (transient) heat flow, by Novikov et al.[37,83] The latter investigators obtained the thermal diffusivity rather than the thermal conductivity. The agreement between the four observers is within ±5% at 750°F but diverges to ±12% at 200°F and ±9% at 1100°F. Above 700°F, Ewing's results agree well with those of Lemmon. Novikov's data are significantly high with respect to Lemmon, while Nikol'skii is somewhat low.

Lemmon et al. also used their electrical resistivity measurements (see discussion below) in conjunction with the thermal conductivity values to obtain a value for the Lorenz constant for temperatures below 800°C (1472°F). This constant was then used with the electrical resistivity data for temperatures above 500°C to obtain thermal conductivities to 2100°F. The values thus derived compared favorably with conductivities calculated by Eq. (1) and indicate the validity of using Lemmon's equation for extrapolation beyond 1472°F.

Tepper et al.[84] also used electrical resistivity measurements to predict the thermal conductivity; their results are shown by Eq. (2) in Table 18. The results of Lemmon and Tepper compare as follows:

| Temperature (°R) | Thermal Conductivity (Btu/hr·ft·°F) | | Difference (%) |
|---|---|---|---|
| | Lemmon (I) | Tepper (II) | (II−I)/I |
| 700 | 29.715 | 35.218 | +18.5 |
| 1400 | 21.787 | 25.308 | +16.2 |
| 2100 | 15.816 | 18.117 | +14.5 |
| 2500 | 12.650 | 14.416 | +14.0 |

Vapor Thermal Conductivity

Values calculated for saturated vapor conductivity by Grosse[85] are recommended; these are shown by Eq. (1) in Table 19 and by the curve in Fig. 17.

Gottlieb and Zollweg[86] report a single value at 1340°F obtained by heat loss measurements from a tungsten filament in a potassium vapor atmosphere at a maximum pressure of 2.2 torr. Their value of 0.01047 Btu/hr·ft·°F at 1800°R is ~19% below that calculated by Grosse using elementary kinetic theory for monatomic gases along with his (Grosse) previous estimates for the viscosity of saturated potassium vapor [Table 17, Eq. (1)].

Weatherford et al.[13] estimated the vapor thermal conductivity from the Prandtl modulus using their calculated values for the vapor viscosity [Table 17, Eq. (2)] and the frozen specific heat as calculated by Shapiro and Meisl.[12] The latter quantity varies from 0.1268 Btu/$lb_m$·°R at 1300°R to 0.1262 Btu/$lb_m$·°R at 2500°R; the Prandtl modulus was arbitrarily chosen to be 0.73. Comparison with the results of Grosse is as follows:

| Temperature (°R) | Vapor Thermal Conductivity (Btu/hr·ft·°F) | | Difference (%) (II−I)/I |
|---|---|---|---|
| | Grosse (I) | Weatherford (II) | |
| 1500 | 0.01136 | 0.00724 | -36.1 |
| 2000 | 0.01312 | 0.00849 | -35.3 |
| 2500 | 0.01467 | 0.00951 | -35.2 |

As noted, the discrepancy between the Weatherford and Grosse results is large. The single experimental value of Gottlieb and Zollweg falls between the two predictions, being ~24% greater than Weatherford's

prediction of 0.00801 Btu/lb·ft·°F at 1800°R and ~19% below Grosse's estimation. While Grosse assumed a monatomic gas, the real gas is a mixture of at least K and $K_2$; and hence, the thermal conductivity should be less than predicted by simple theory. This trend would tend to support the experimental value given by Gottlieb and Zollweg. It should also be noted that the temperature dependency is essentially the same for either prediction.

## Electrical Resistivity

While the electrical resistivity of a liquid is needed in some applications (e.g., in the design of control and measurement instrumentation), major interest in this property derives from the relative ease in performing electrical resistivity measurements as opposed to thermal conductivity measurements. The Wiedemann-Franz-Lorenz (W-F-L) relationship,

$$k\,\rho_e/T = L \quad ,$$

is then used to calculate the thermal conductivity, k, from the resistivity, $\rho_e$; T is the absolute temperature, and L is the W-F-L constant. Sommerfeld deduced through quantum mechnics that at 0°C:

$$L_o = \pi^2\,\kappa^2/3\epsilon^2 = 2.57 \times 10^{-8} \quad [\text{Btu}\cdot\text{ohm/hr}\cdot(°\text{R})^2]$$

$$= 2.45 \times 10^{-8} \quad [v^2/(°\text{C})^2] \quad ,$$

where $\kappa$ = the Boltzmann constant and $\epsilon$ = the elementary charge of an electron. For molten metals, the W-F-L relation should give thermal conductivities close to actual values. However, comparisons made with several liquid metals whose thermal conductivities and electrical resistivities are well-known give k predictions higher than the experimental values. It has

not yet been resolved whether the discrepancies result from a breakdown in the theory or from inaccuracies in the experimental measurements.

Liquid Resistivity

The results of three experimental investigations is given in Table 20. A comparison of these data sets is as follows:

| Temperature (°R) | Electrical Resistivity (microohm-cm) | | |
|---|---|---|---|
| | Tepper | Kapelner | Deem |
| 672 | 14.3 | 15.8 | 15.4 |
| 1392 | 43.0 | 44.7 | 44.4 |
| 2112 | 92.7 | (93.6)[a] | 93.8 |
| 2607 | 149.6 | (145.1)[a] | 153.0 |

[a]Extrapolation beyond data range.

The results of Deem and Matolich[87] and of Kapelner and Bratton[88] show excellent agreement to 2300°F (~0.5%); note that Kapelner's values above 1800°R are extrapolated using Eq. (1) in Table 20. Tepper et al.[84] data fall below Deem at temperatures below 2100°R, being ~7% at 672°R, ~3% at 1392°R, and ~1% at 2112°R.

Deem and Matolich values (also reported in Ref. 15) are recommended; their results are listed in Table 20 as Eq. (3) and plotted in Fig. 18.

Wiedemann-Franz-Lorenz Constant

Deem and Matolich[15,87] deduced from their thermal and electrical conductivity data at temperatures to 800°C an average value for the W-L-F constant of $2.14 \times 10^{-8}$ $v^2/(°C)^2$; this is 13% below the theoretical value noted above. Kapelner and Bratton,[88] using their measurements for $\rho_e$ and

Ewing's[82] k values, found a nearly linear relationship in temperature with L ranging from $2.07 \times 10^{-8}$ $v^2/°C)^2$ at 200°C to $2.21 \times 10^{-8}$ $v^2/(°C)^2$ at 600°C. It is interesting, though not particularly illuminating, to note that the average value of Kapelner and Bratton over this temperature span [$2.14 \times 10^{-8}$ $v^2/(°C)^2$] coincides with Deem's value.

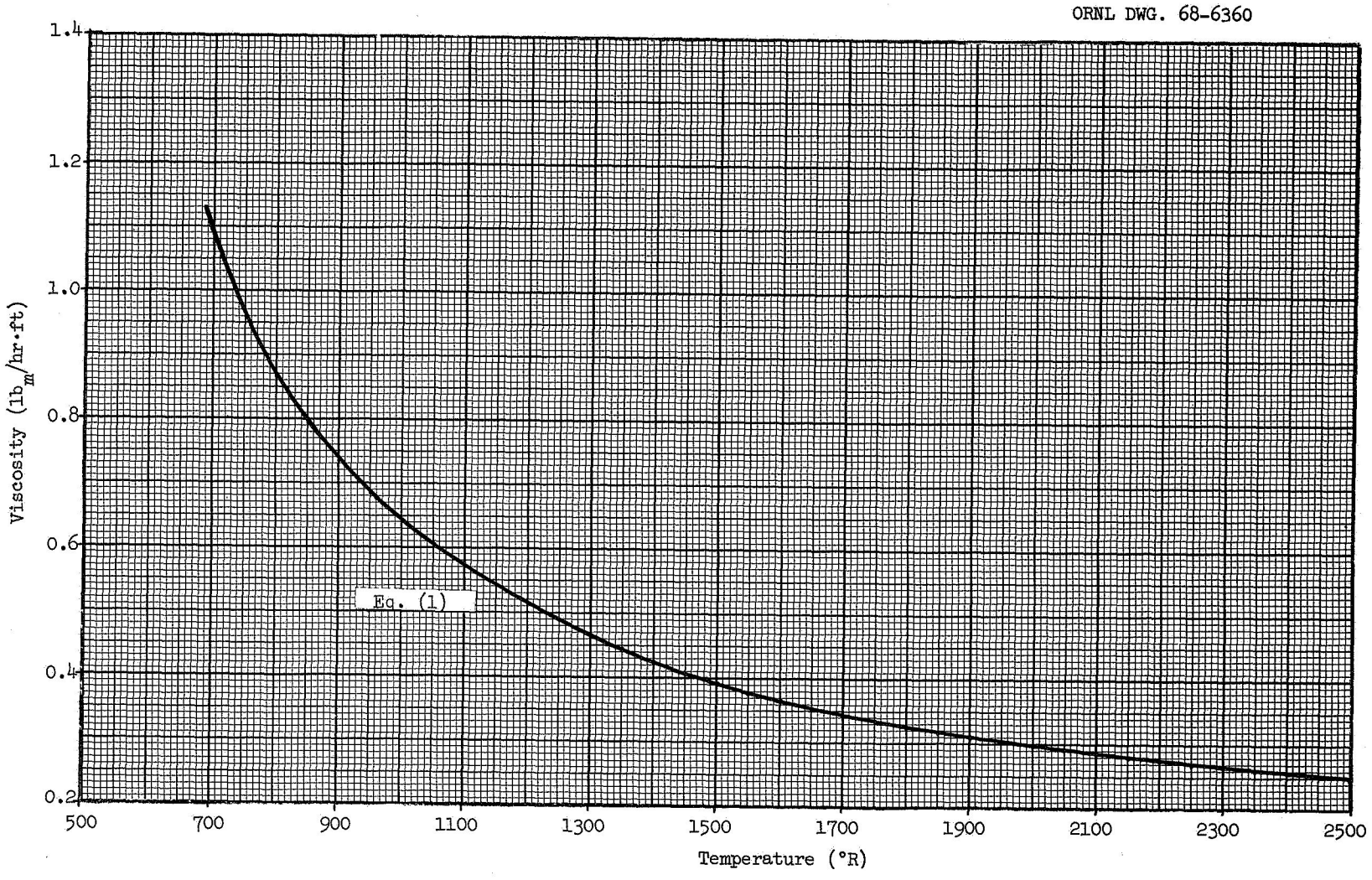


Fig. 14. Potassium: Liquid Viscosity.

Table 16. Liquid Viscosity

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $\log_{10} \mu = \frac{516.8}{T} - 0.7073$<br>$\log_{10} \mu = \frac{737.5}{T} - 0.8979$<br>[$\mu$ = $lb_m$/ft·hr; T = °R] | (1-a)<br>(1-b) | 154–698<br>698–2100 | 0.5%<br>1.2% | Oscillating cylinder | Andrade plot yielded best fit with two straight lines rather than with a single line | Lemmon et al. (1963) | 15 |
| $\log_{10} \mu = -1.1973 - 0.6100 \log_{10} T + 159.97/T$<br>[$\mu$ = g/cm·sec; T = °K] | (2) | mp–1832 | ±1% | Oscillating cylinder | | Shpil'rain et al. (1965) | 75 |
| T / $\nu = \mu/\rho$<br>100 / 56.1<br>200 / 42.8<br>400 / 29.8<br>600 / 22.1<br>700 / 20.5<br>[T = °C; $\nu$ = $m^2$/sec; $\mu$ = g/m·sec; $\rho$ = $g/m^3$] | (3) | | | Oscillating cylinder | Tabulated by Kutateladze et al. | Novikov et al. (1956) | 37 |
| T / $\mu$ / T / $\mu$<br>336.9 / 0.560 / 1600 / 0.092<br>400 / 0.384 / 2000 / 0.077<br>800 / 0.162 / 2400 / 0.062<br>1200 / 0.113<br>[T = °K; $\mu$ = centipoise] | (4) | 147–3950 | | Calculated | Used data of Ewing et al. to 800°K and of Lemmon et al. from 800°K to 1400°K; values above 1400°K estimated | Grosse (1965) | 78 |
| $\mu/\rho^{1/3} = 0.9114 \times 10^{-3}\, e^{742.8\, \rho/T}$<br>$\mu/\rho^{1/3} = 0.9673 \times 10^{-3}\, e^{716.0\, \rho/T}$<br>[$\mu$ = centipoise; $\rho$ = $g/cm^3$; T = °C] | (5-a)<br>(5-b) | mp–374<br>374–662 | ±2%<br>±2% – ±10% | Glass & nickel Ostwald viscometers | Coefficients in Andrade type equation developed from limited experimental data | Ewing et al. (1954) | 77 |
| $\mu/\rho^{1/3} = 1.293 \times 10^{-3}\, e^{600.0\, \rho/T}$<br>[$\mu$ = centipoise; $\rho$ = $g/cm^3$; T = °C] | (6) | mp– 665 | | Oscillating cylinder | | Chiong (1936) | 76 |
| See Appendix A | (7) | | | Theoretical | A corresponding states correlation based on atomic parameters | Chapman (1965) | 74 |

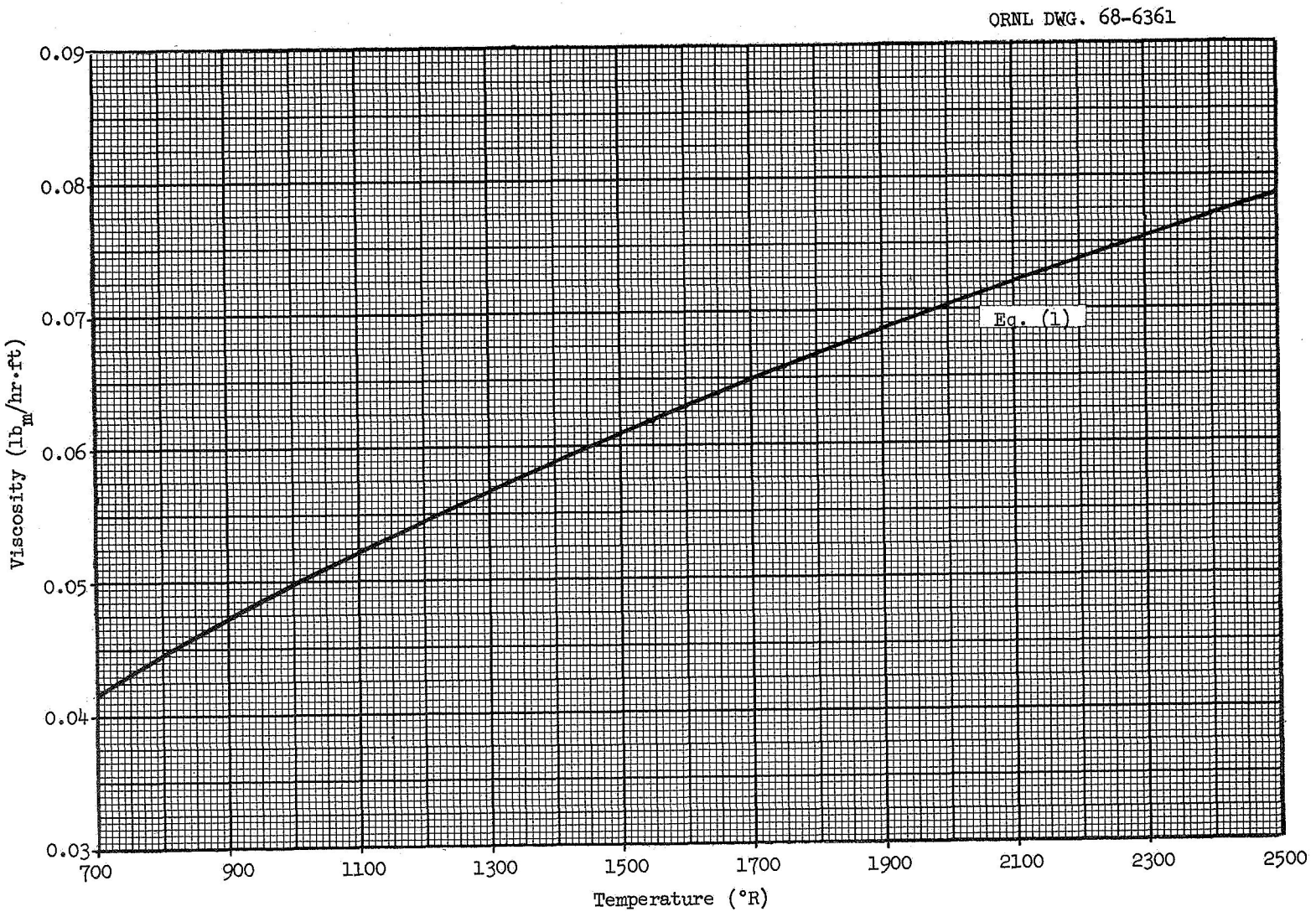


Fig. 15. Potassium: Saturated Vapor Viscosity.

Table 17. Saturated Vapor Viscosity

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| T / μ<br>400 / 0.0175<br>1000 / 0.0216<br>1600 / 0.0340<br>[μ = centipoise; T = °K] | (1) | | | Calculated | For dilute vapor | Grosse (1965) | 78 |
| T / μ<br>1100 / 0.0427<br>1400 / 0.0471<br>1700 / 0.0512<br>2000 / 0.0546<br>[μ = $lb_m$/hr·ft; T = °F] | (2) | 840–2240 | | Calculated | For variable molecular weight saturated vapor; values read from curve in Ref. 13 | Weatherford et al. (1961) | 13 |

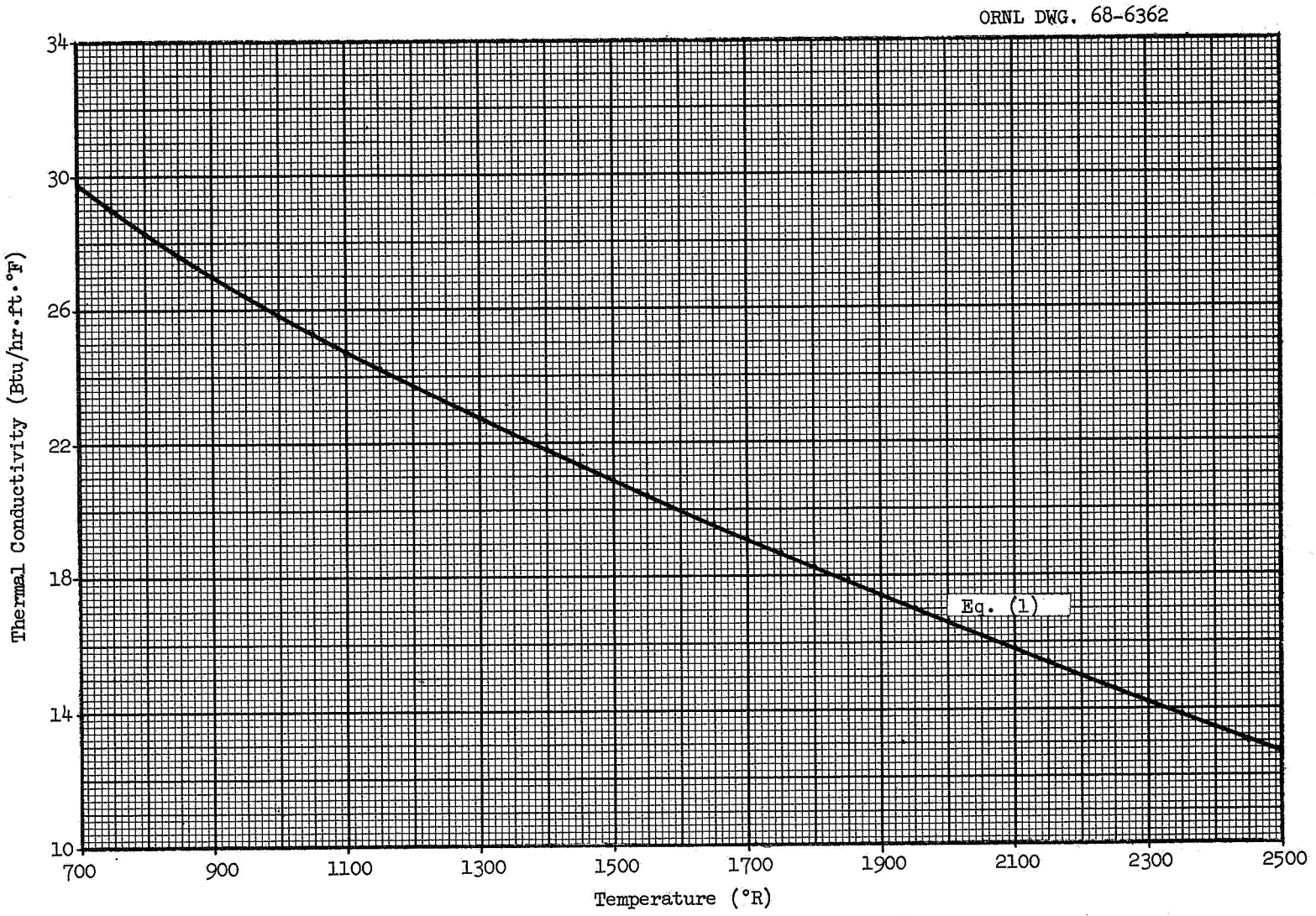


Fig. 16. Potassium: Liquid Thermal Conductivity.

Table 18. Liquid Thermal Conductivity

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigaror (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $k = 0.438 - 2.22 \times 10^{-4}\ T + \frac{39.5}{T + 273.2}$<br>[k = w/cm·°C; T = °C] | (1) | 212–1472 | 0.011 w/cm·°C | Steady-state, longitudinal heat flow | Investigator claims that check using Wiedemann-Franz-Lorenz equation shows listed k equation valid for extrapolation to 2100°F | Lemmon et al. (1963) | 15,87 |
| $k = 0.96689 - 4.7904 \times 10^{-4}\ T + 1.3778 \times 10^{-7}\ T^2 - 2.4884 \times 10^{-11}\ T^3$<br>[k = w/in.·°F; T = °F] | (2) | mp–2000 | | Derived | Calculated from electrical resistivity data through W-F-L relationship | Tepper et al. (1965) | 84 |
| T / k<br>200 / 0.454<br>300 / 0.424<br>400 / 0.397<br>500 / 0.374<br>600 / 0.356<br>700 / 0.340<br>800 / 0.326<br>[k = w/cm·°C; T = °C] | (3) | | 1% | Steady-state, longitudinal heat flow | Measured at 610°C; extrapolated to 800°C | Ewing et al. (1952) | 82 |
| T / k<br>300 / 37.3<br>350 / 35.8<br>400 / 34.0<br>450 / 32.0<br>500 / 30.0<br>550 / 28.2<br>[k = kcal/m·hr·°C; T = °C] | (4) | | | Successive stationary states | | Nikol'skii et al. (1959) | 46 |
| T / $\alpha = k/\rho\ C_p$<br>100 / 0.33<br>200 / 0.31<br>300 / 0.28<br>400 / 0.26<br>500 / 0.26<br>600 / 0.25<br>[$\alpha = m^2/hr$; k = Kcal/m·hr·°C;<br>$\rho = g/m^3$; $C_p$ = Kcal/g·°C; T = °C] | (5) | 212–1157 | 0.5% | Temperature waves (transient) | Measured thermal diffusivity; tabulated values approximated from small plot | Novikov et al. (1956) | 37 |

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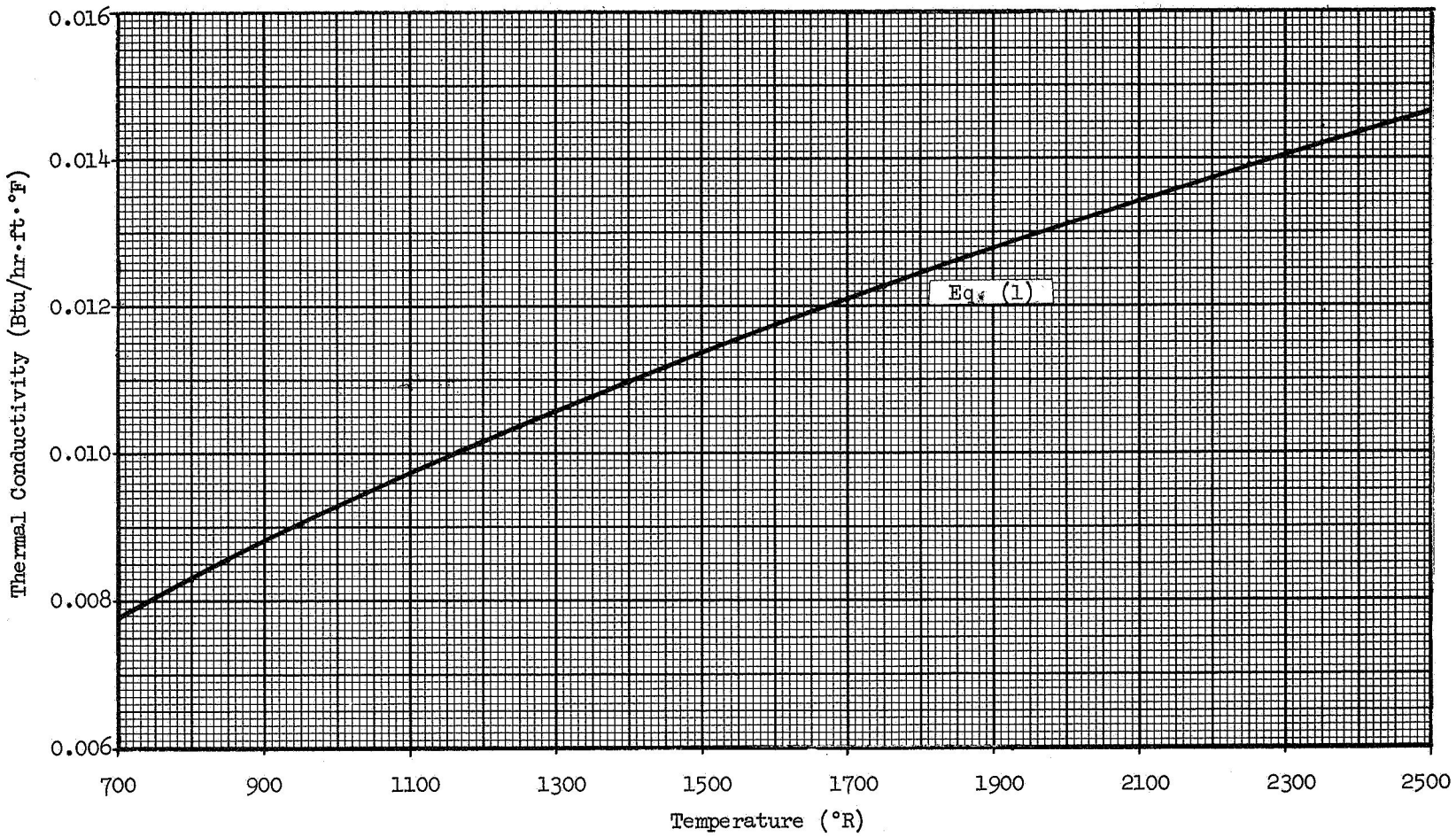


Fig. 17. Potassium: Saturated Vapor Thermal Conductivity.

Table 19. Saturated Vapor Thermal Conductivity

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $k = 0.7803\ \mu$<br>[$k$ = w/cm·°K; $\mu$ = poise] | (1) | To critical temperature (2450°K) | | Calculated | Used elementary kinetic theory for monatomic gases and investigator's previous estimates for viscosity of saturated K vapor | Grosse (1966) | 85 |
| $k = 1.81 \times 10^{-4}$ w/cm·°K | (2) | at 1340 | | Heat loss from W filament | Limiting value at high pressure (2.2 torr) | Gottlieb & Zollweg (1963) | 86 |
| T / k<br>1100 / 0.00740<br>1400 / 0.00816<br>1700 / 0.00886<br>2000 / 0.00945<br>[$k$ = Btu/hr·ft·°F; $T$ = °F] | (3) | | | Calculated | Used frozen specifid heat and calculated vapor viscosity with assumed Prandtl modulus of 0.73 | Weatherford et al. (1961) | 13 |

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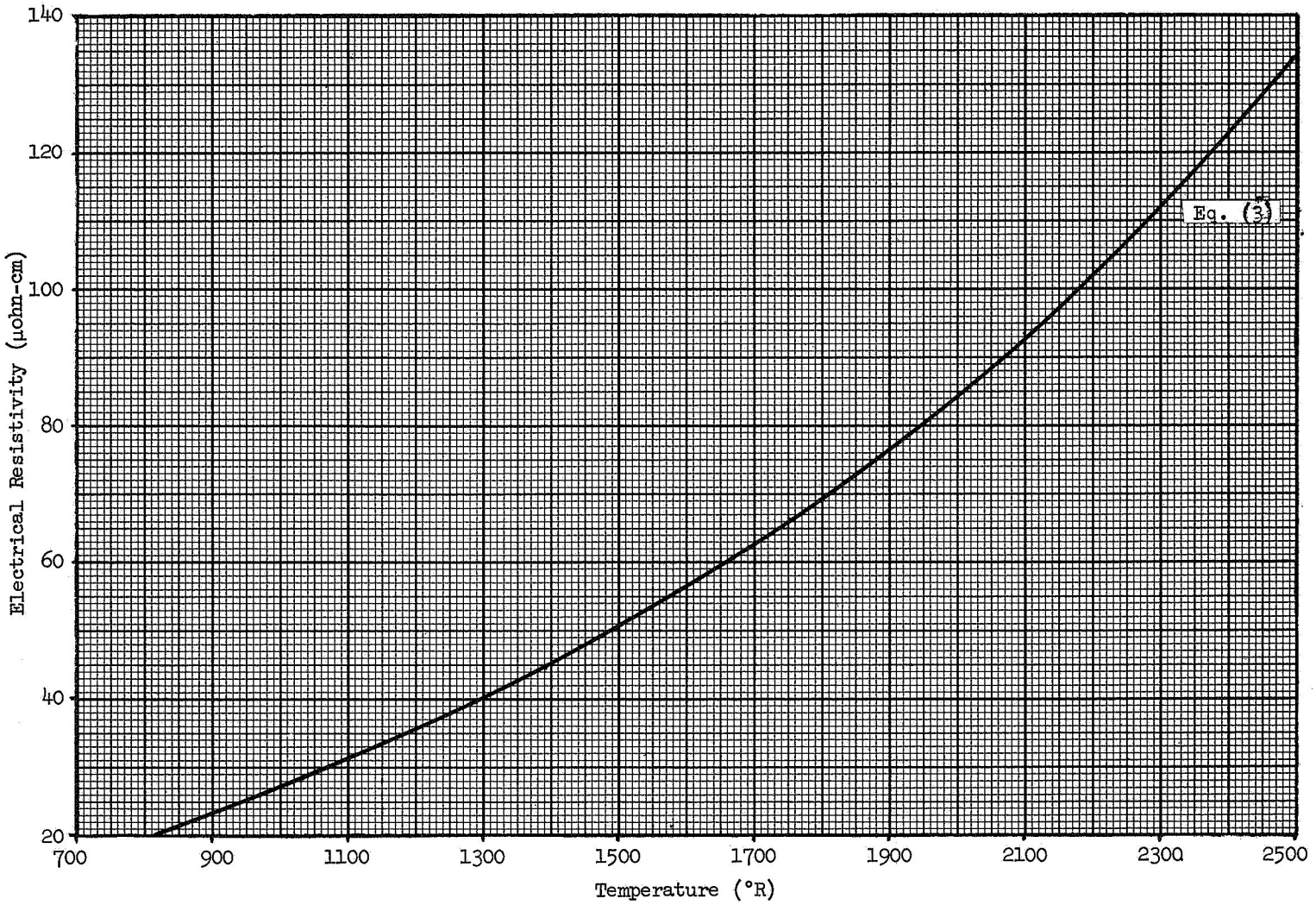


Fig. 18. Potassium: Liquid Electrical Resistivity.

Table 20. Liquid Electrical Resistivity

| Equation | Eq. No. | Temperature Range (°F) | Estimated Error | Method | Comments | Investigator (Date) | Refs. |
|---|---|---|---|---|---|---|---|
| $\rho_e = 10.324 + 5.302 \times 10^{-2}\ T + 1.559 \times 10^{-5}\ T^2 + 3.140 \times 10^{-8}\ T^3$ [$\rho_e$ = μohm-cm; T = °C] | (1) | 174 –1407 | ±0.71% | Kelvin bridge and equation of parallel resistors | Measured potential drop using a known current | Kapelner & Bratton (1962) | 88 |
| $\rho_e = 2.6978 + 1.4055 \times 10^{-3}\ T - 2.0398 \times 10^{-6}\ T^2 + 3.5792 \times 10^{-9}\ T^3$ [$\rho_e$ = μohm-in.; T = °F] | (2) | mp–2000 | 1.0% | Kelvin bridge and equation of parallel resistors | | Tepper et al. (1965) | 84 |
| T / $\rho_e$: 100 / 15.4; 300 / 28.4; 500 / 44.4; 700 / 66.4; 900 / 93.8; 1100 / 131; 1175 / 153 [$\rho_e$ = μohm-cm; T = °C] | (3) | mp–2150 | Values significant to two figures only | See Comments | Measured potential drop across specimen; current measured by precision resistor; smoothed, interpolated values shown | Deem & Matolich (1963) | 87 |

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# NOMENCLATURE

| | |
|---|---|
| a, b | Constants in van der Waals' equation of state |
| $A_i$, $B_i$ | Constants for ith component in quasi-chemical equation of state |
| A, C | Constants in Andrade's viscosity equation |
| b | Coefficient in Hicks' equation of state (Table 4) |
| B, C, D, E, F, B′, C′ | Virial coefficients in equations of state (Table 4) |
| c | Sonic velocity |
| $C_p$ | Heat capacity at constant pressure; $C_{p,s}$, at saturation conditions; $C_{p,liq}$, $C_{p,\ell}$, liquid |
| F | Free energy; $F^o$, standard state; $F_T$, at temperature T |
| $h_{fg} = \Delta H_{vap}$ | Latent heat of vaporization; $\Delta H^o$, standard state; $\Delta H_T$, at temperature T |
| H | Enthalpy; $H^o$, standard state; $H_T$, $H^T$, at temperature T; $H_g$, vapor |
| J | Mechanical equivalent of heat ($4.1858 \times 10^7$ erg/cal) |
| k | Thermal conductivity; $k_\ell$, liquid |
| $k_i$ | Equilibrium constant for ith component in quasi-chemical equation of state |
| K | Liquid compressibility; $K_S$, adiabatic; $K_T$, isothermal |
| L, $L_o$ | Lorenz number ($= k\,\rho_e/T$) |
| m | Exponent in Hicks' equation of state (Table 4) |
| M | Molecular weight; $M_a$, equilibrium mixture; $M_1$, monomer |
| n | Exponent in Eötvos surface tension relation; also number of moles of vapor |
| P | Pressure; $P_c$, $P_{crit}$, critical; $P_s$, $P_{sat}$, saturation |
| $q_y$ | Heat flux in y-direction |
| Q | Quantity defined by Hicks ($= \Delta H^o + bP/T^m$) |

| | |
|---|---|
| $R$ | Gas constant |
| $S$ | Entropy; $S^o$, standard state; $S_T$, $S^T$, at temperature T; $S_{sat}$, at saturation temperature; $S_g$, vapor |
| $T$ | Temperature, $T_c$, $T_{crit}$, critical; $T_s$, $T_{sat}$, saturation; $T_r$, reduced ($= T/T_c$); $T_M$, melting; $T_B$, boiling |
| $v$ | Velocity; $v_x$, in x-direction |
| $V$ | Volume; $V_c$, $V_{crit}$, critical; $V_s$, $V_{sat}$, saturation; $V_\ell$, liquid; $V_g$, vapor; $V^o$, standard state; $V_m$, at melting temperature; $\tilde{V}$, molal |
| $x, y, z$ | Cartesian coordinate directions |
| $z$ | Compressibility factor ($= P\tilde{V}/RT$) |
| $\alpha$ | Thermal diffusivity ($= k/\rho\, C_p$) |
| $\epsilon$ | Elementary charge of an electron |
| $\kappa$ | Boltzmann constant |
| $\mu$ | Absolute viscosity; $\mu_{vap}$, vapor |
| $\nu$ | Kinematic viscosity ($= \mu/\rho$) |
| $\rho$ | Density; $\rho_\ell$, $\rho_{liq}$, liquid; $\rho_v$, $\rho_{vap}$, vapor; $\rho_{sat}$, saturation |
| $\rho_e$ | Electrical resistivity |
| $\sigma$ | Surface tension; $\sigma^o$, standard state, $\sigma_m$, at melting temperature |
| $\sigma_o$ | Hard-core collision diameter |
| $\tau$ | Time |
| $\tau_{yx}$ | Shear stress, or viscous flux of x-momentum in y-direction |

## APPENDIX A

## CHAPMAN'S METHOD FOR ESTIMATING THE VISCOSITY OF LIQUID METALS

The following abstract is taken from Chapman:

> "An approximate form is suggested for the perturbation of the radial distribution function of a monatomic liquid by a nonuniform flow field. Substitution of this form into the microscopic expression for the pressure tensor yields an equation for liquid viscosity in terms of the equilibrium distribution function and the interatomic potential energy function. This equation establishes the basis for a corresponding states correlation of the viscosity of liquid metals based on atomic parameters.
>
> "The viscosity data for twenty-one molten metals are made to fall on a single curve by the adjustment of one microscopic parameter. It is found that this empirically determined parameter apparently has the proper fundamental significance. Therefore, it is possible to estimate it independently and to use the general correlation for estimating the viscosity of a metal for which data are not available. It is also suggested that the atomic parameters determined here might be used to correlate other properties of the liquid metals."

An explicit expression is obtained for the liquid viscosity which involves the pair potential function, $\phi(r)$, and the radial distribution function, $g^{o}(r)$. With the assumptions made, the problem of liquid viscosity is reduced to the same level of complexity as the problem of the thermodynamic properties. The potential function is then assumed to depend on an energy parameter, $\epsilon$, and a distance parameter, $\delta$; and the general equation is expressed in dimensionless form, $\mu^* = F(T^*, V^*)$, where:

$$\eta^* = \text{reduced viscosity} = \frac{\mu\delta^2 N_o}{(MRT)^{1/2}} \quad ,$$

$$T^* = \text{reduced temperature} = kT/\epsilon \quad ,$$

$$V^* = \text{reduced volume} = 1/n\delta^3 \quad ,$$

and

$\mu$ = viscosity (poise = g/cm·sec),

$\delta$ = atomic diameter (cm),

$N_o$ = Avagadro's number = $6.064 \times 10^{23}$ (1/g-mole),

M = atomic weight (g/g-mole),

R = gas constant = $8.31339 \times 10^7$ ($g \cdot cm^2/°K \cdot g\text{-mole} \cdot sec^2$),

$\epsilon$ = $5.20\ kT_m$,

T = any absolute temperature (°K),

$T_m$ = melting temperature (°K),

n = particle number density = $\rho_T N_o/M$ ($1/cm^3$),

$\rho_T$ = density at temperature, T ($g/cm^3$).

Chapman then postulates that $\mu^*(V^*)^2$ should be a universal function of $T^*$ only; i.e., $\mu^*(V^*)^2 = G(T^*)$. To obtain the functional form of this equation, Chapman utilizes the effective Lennard-Jones parameters for liquid sodium and potassium as determined by Ling[89] from experimental x-ray scattering curves. Further, the value of $\delta$ is assumed to be the interatomic distance in the close-packed crystal at 0°K. This was obtained by crystallographic data and is well-known for nearly all metals. With this estimate of $\delta$, $\mu^*(V^*)^2$ was calculated for some 21 different metals for which viscosity and density data exist. The general $\mu^*(V^*)^2$ vs $1/T^*$ curve for Na and K was then used to evaluate $\epsilon$ for the other metals. The resulting correlation is shown in Fig. 19 taken from Chapman. This

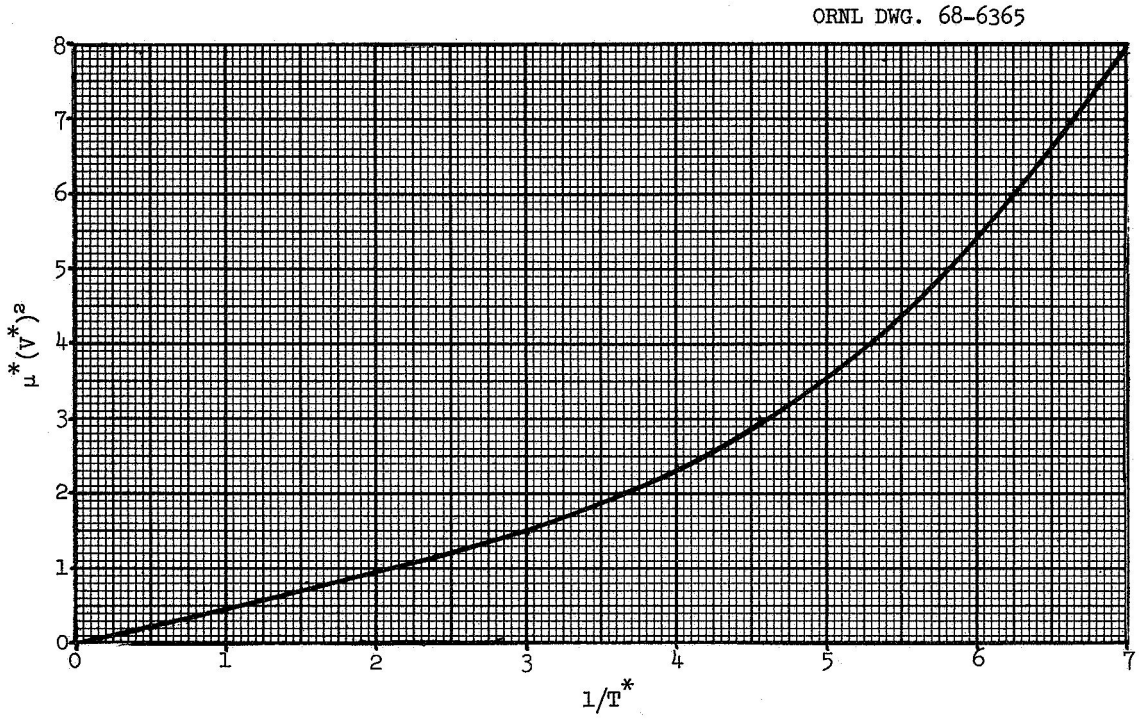


Fig. 19. Dimensionless Viscosity Correlation According to Chapman.

is based on liquid metals as diverse as lithium, mercury, iron, and plutonium with densities ranging from 1.8 to 18, viscosities from 0.2 to 7 centipoise, atomic weights from 6.9 to 242, and melting temperatures from 234 to 1800°K.

For the alkali metals, values of $\delta$ and $\epsilon/k$ are as follows:

| Metal | $\delta$ (Å) | $\epsilon/k$ (°K) | M |
|---|---|---|---|
| Li | 3.14 | 2350 | 6.939 |
| Na | 3.84 | 1970 | 22.9898 |
| K | 4.76 | 1760 | 39.102 |
| Rb | 5.04 | 1600 | 85.47 |
| Cs | 5.40 | 1550 | 132.905 |

Sample Calculation. An example showing in detail the application of this technique for predicting viscosity is given below. Following Chapman, thallium was selected for illustration.

Atomic weight = 204.4 g/g-mole

Melting temperature, $T_m$ = 576°K

Selected temperature, T = 644°K

Density at 644°K = 11.18 g/cm$^3$

$\delta$ = 3.40 Å = $3.40 \times 10^{-8}$ cm

R = $8.31339 \times 10^7$ g·cm$^2$/°K·g-mole·sec$^2$

$$\epsilon/k = 5.20\ T_m \quad , \tag{1}$$

$$\epsilon = (2995.2\ k)\ °K \quad .$$

Thus,

$$T^* = \frac{kT}{\epsilon} = \frac{644\ k}{2995.2\ k} = 0.2150 \quad ,$$

and

$$\frac{1}{T^*} = 4.65094 \quad .$$

Then, from Fig. 19,

$$\mu^*(V^*)^2 = 3.05 \quad . \tag{2}$$

Further,

$$n = \rho_T \, N_o/M = \frac{(11.18)(6.064 \times 10^{23})}{204.4} = 0.33168 \times 10^{23} \, \frac{1}{cm^3} \quad ,$$

and

$$V^* = 1/n\delta^3 = 1/(0.33168 \times 10^{23})(39.304 \times 10^{-24})$$

$$= 0.76708$$

Then, using Eq. (1),

$$\mu^* = 3.05 \, /(0.76708)^2 = 5.18346 \quad .$$

Since,

$$\mu^* = \frac{\mu\delta^2 N_o}{(MRT)^{1/2}} \quad ,$$

$$\mu = \mu^* \, \frac{(MRT)^{1/2}}{\delta^2 N_o}$$

$$= (5.18346) \, \frac{[(2.044 \times 10^2)(6.44 \times 10^2)(8.31339 \times 10^7)]^{1/2}}{(3.40 \times 10^{-8})^2 (6.064 \times 10^{23})}$$

$$= 2.4461 \times 10^{-2} \text{ g/cm·sec (poise)} \quad ,$$

or

$$\mu = 2.4461 \text{ centipoise} \quad .$$

As pointed out by Chapman, this compares quite favorably with the measured value of 2.11 centipoise. More important, perhaps, is that predicted dependence on temperature parallels closely the experimental results. Thus, this technique should be quite useful for extrapolating viscosities to temperatures well beyond the limit of measurements.

## APPENDIX B

## THERMODYNAMIC PROPERTIES OF POTASSIUM SUPERHEATED VAPOR

(Monomer Gas Base)

Tabulated values were taken from Ewing et al.,[14] Appendix B. Initial value at each temperature level corresponds to saturation conditions. The units for the listed properties are as follows:

$t$ = °F,

$p$ = atm abs,

$v^g$ = $ft^3/lb_m$,

$h^g$ = $Btu/lb_m$,

$s^g$ = $Btu/lb_m \cdot °F$,

$c_p^g$ = $Btu/lb_m \cdot °F$,

$z$ = dimensionless.

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 1400. | 1.0327 | 30.9486 | .92025 | 1188.81 | 1.11434 | .2842 |
| 1400. | 1.0000 | 32.0491 | .92276 | 1190.30 | 1.11664 | .2789 |
| 1400. | .8000 | 40.7307 | .93818 | 1199.36 | 1.13207 | .2473 |
| 1400. | .6000 | 55.2017 | .95363 | 1208.38 | 1.15075 | .2163 |
| 1400. | .4000 | 84.1450 | .96909 | 1217.35 | 1.17538 | .1859 |
| 1400. | .2000 | 170.9752 | .98455 | 1226.27 | 1.21460 | .1561 |
| 1425. | 1.1719 | 27.5353 | .91673 | 1189.89 | 1.10902 | .2869 |
| 1425. | 1.0000 | 32.6950 | .92887 | 1197.06 | 1.12026 | .2625 |
| 1425. | .8000 | 41.4924 | .94305 | 1205.38 | 1.13528 | .2344 |
| 1425. | .6000 | 56.1570 | .95726 | 1213.66 | 1.15357 | .2068 |
| 1425. | .4000 | 85.4884 | .97150 | 1221.92 | 1.17782 | .1797 |
| 1425. | .2000 | 173.4846 | .98575 | 1230.13 | 1.21667 | .1531 |
| 1450. | 1.3252 | 24.5767 | .91320 | 1190.96 | 1.10386 | .2894 |
| 1450. | 1.0000 | 33.3235 | .93434 | 1203.44 | 1.12362 | .2482 |
| 1450. | .8000 | 42.2372 | .94741 | 1211.09 | 1.13829 | .2232 |
| 1450. | .6000 | 57.0956 | .96052 | 1218.73 | 1.15624 | .1986 |
| 1450. | .4000 | 86.8153 | .97366 | 1226.34 | 1.18015 | .1744 |
| 1450. | .2000 | 175.9780 | .98683 | 1233.93 | 1.21867 | .1505 |
| 1475. | 1.4938 | 22.0034 | .90965 | 1192.01 | 1.09887 | .2917 |
| 1475. | 1.0000 | 33.9369 | .93924 | 1209.48 | 1.12676 | .2358 |
| 1475. | .8000 | 42.9669 | .95132 | 1216.55 | 1.14113 | .2135 |
| 1475. | .6000 | 58.0195 | .96345 | 1223.60 | 1.15877 | .1914 |
| 1475. | .4000 | 88.1277 | .97561 | 1230.64 | 1.18239 | .1697 |
| 1475. | .2000 | 178.4570 | .98780 | 1237.66 | 1.22061 | .1482 |
| 1500. | 1.6785 | 19.7578 | .90610 | 1193.06 | 1.09403 | .2938 |
| 1500. | 1.0000 | 34.5370 | .94365 | 1215.24 | 1.12972 | .2249 |
| 1500. | .8000 | 43.6836 | .95485 | 1221.78 | 1.14382 | .2049 |
| 1500. | .6000 | 58.9304 | .96609 | 1228.31 | 1.16119 | .1851 |
| 1500. | .4000 | 89.4273 | .97737 | 1234.83 | 1.18454 | .1655 |
| 1500. | .2000 | 180.9234 | .98867 | 1241.34 | 1.22250 | .1461 |
| 1525. | 1.8803 | 17.7920 | .90255 | 1194.10 | 1.08934 | .2957 |
| 1525. | 1.0000 | 35.1253 | .94764 | 1220.74 | 1.13251 | .2154 |
| 1525. | .8000 | 44.3885 | .95804 | 1226.80 | 1.14637 | .1974 |
| 1525. | .6000 | 59.8297 | .96848 | 1232.86 | 1.16350 | .1796 |
| 1525. | .4000 | 90.7154 | .97896 | 1238.92 | 1.18662 | .1619 |
| 1525. | .2000 | 183.3785 | .98947 | 1244.97 | 1.22434 | .1443 |
| 1550. | 2.1003 | 16.0657 | .89900 | 1195.14 | 1.08480 | .2974 |
| 1550. | 2.0000 | 16.9589 | .90368 | 1197.94 | 1.08843 | .2891 |
| 1550. | 1.0000 | 35.7032 | .95125 | 1226.02 | 1.13515 | .2070 |
| 1550. | .8000 | 45.0830 | .96092 | 1231.65 | 1.14880 | .1908 |
| 1550. | .6000 | 60.7186 | .97064 | 1237.29 | 1.16572 | .1747 |
| 1550. | .4000 | 91.9934 | .98040 | 1242.93 | 1.18862 | .1586 |
| 1550. | .2000 | 185.8235 | .99019 | 1248.56 | 1.22614 | .1428 |
| 1575. | 2.3394 | 14.5453 | .89547 | 1196.18 | 1.08040 | .2988 |
| 1575. | 2.0000 | 17.2931 | .91016 | 1204.97 | 1.09191 | .2737 |
| 1575. | 1.0000 | 36.2717 | .95452 | 1231.10 | 1.13767 | .1996 |
| 1575. | .8000 | 45.7683 | .96354 | 1236.35 | 1.15112 | .1849 |
| 1575. | .6000 | 61.5984 | .97261 | 1241.60 | 1.16785 | .1703 |
| 1575. | .4000 | 93.2621 | .98171 | 1246.86 | 1.19056 | .1558 |
| 1575. | .2000 | 188.2594 | .99084 | 1252.11 | 1.22789 | .1413 |
| 1600. | 2.5988 | 13.2023 | .89195 | 1197.23 | 1.07614 | .3001 |
| 1600. | 2.0000 | 17.6188 | .91605 | 1211.64 | 1.09517 | .2602 |
| 1600. | 1.0000 | 36.8319 | .95750 | 1236.01 | 1.14006 | .1931 |
| 1600. | .8000 | 46.4452 | .96593 | 1240.91 | 1.15334 | .1797 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 1600. | .6000 | 62.4699 | .97440 | 1245.81 | 1.16991 | .1664 |
| 1600. | .4000 | 94.5227 | .98290 | 1250.72 | 1.19245 | .1532 |
| 1600. | .2000 | 190.6872 | .99144 | 1255.62 | 1.22961 | .1401 |
| 1625. | 2.8795 | 12.0129 | .88845 | 1198.28 | 1.07201 | .3011 |
| 1625. | 2.0000 | 17.9371 | .92142 | 1217.99 | 1.09823 | .2482 |
| 1625. | 1.0000 | 37.3846 | .96021 | 1240.76 | 1.14236 | .1873 |
| 1625. | .8000 | 47.1147 | .96810 | 1245.34 | 1.15548 | .1751 |
| 1625. | .6000 | 63.3341 | .97603 | 1249.93 | 1.17189 | .1630 |
| 1625. | .4000 | 95.7760 | .98399 | 1254.52 | 1.19429 | .1509 |
| 1625. | .2000 | 193.1077 | .99198 | 1259.11 | 1.23129 | .1389 |
| 1650. | 3.1824 | 10.9566 | .88498 | 1199.34 | 1.06801 | .3019 |
| 1650. | 3.0000 | 11.7048 | .89121 | 1203.11 | 1.07246 | .2921 |
| 1650. | 2.0000 | 18.2487 | .92631 | 1224.06 | 1.10113 | .2375 |
| 1650. | 1.0000 | 37.9306 | .96269 | 1245.37 | 1.14456 | .1821 |
| 1650. | .8000 | 47.7776 | .97009 | 1249.67 | 1.15755 | .1710 |
| 1650. | .6000 | 64.1915 | .97752 | 1253.96 | 1.17382 | .1599 |
| 1650. | .4000 | 97.0226 | .98498 | 1258.27 | 1.19607 | .1489 |
| 1650. | .2000 | 195.5215 | .99248 | 1262.57 | 1.23294 | .1379 |
| 1675. | 3.5088 | 10.0162 | .88153 | 1200.42 | 1.06414 | .3025 |
| 1675. | 3.0000 | 11.9309 | .89779 | 1210.23 | 1.07581 | .2778 |
| 1675. | 2.0000 | 18.5542 | .93079 | 1229.88 | 1.10387 | .2280 |
| 1675. | 1.0000 | 38.4706 | .96496 | 1249.87 | 1.14667 | .1774 |
| 1675. | .8000 | 48.4344 | .97191 | 1253.89 | 1.15954 | .1673 |
| 1675. | .6000 | 65.0430 | .97889 | 1257.93 | 1.17568 | .1572 |
| 1675. | .4000 | 98.2632 | .98590 | 1261.97 | 1.19782 | .1471 |
| 1675. | .2000 | 197.9294 | .99293 | 1266.01 | 1.23456 | .1370 |
| 1700. | 3.8596 | 9.1768 | .87812 | 1201.52 | 1.06039 | .3029 |
| 1700. | 3.0000 | 12.1516 | .90382 | 1217.02 | 1.07897 | .2651 |
| 1700. | 2.0000 | 18.8544 | .93490 | 1235.47 | 1.10647 | .2196 |
| 1700. | 1.0000 | 39.0051 | .96704 | 1254.25 | 1.14871 | .1733 |
| 1700. | .8000 | 49.0857 | .97357 | 1258.03 | 1.16147 | .1640 |
| 1700. | .6000 | 65.8890 | .98014 | 1261.82 | 1.17750 | .1547 |
| 1700. | .4000 | 99.4983 | .98673 | 1265.62 | 1.19952 | .1455 |
| 1700. | .2000 | 200.3319 | .99335 | 1269.42 | 1.23615 | .1362 |
| 1725. | 4.2359 | 8.4257 | .87474 | 1202.63 | 1.05676 | .3030 |
| 1725. | 4.0000 | 8.9885 | .88120 | 1206.56 | 1.06111 | .2939 |
| 1725. | 3.0000 | 12.3677 | .90936 | 1223.50 | 1.08196 | .2537 |
| 1725. | 2.0000 | 19.1496 | .93867 | 1240.86 | 1.10896 | .2120 |
| 1725. | 1.0000 | 39.5346 | .96895 | 1258.53 | 1.15069 | .1695 |
| 1725. | .8000 | 49.7322 | .97511 | 1262.09 | 1.16334 | .1610 |
| 1725. | .6000 | 66.7300 | .98129 | 1265.66 | 1.17927 | .1525 |
| 1725. | .4000 | 100.7286 | .98750 | 1269.24 | 1.20118 | .1440 |
| 1725. | .2000 | 202.7295 | .99374 | 1272.82 | 1.23772 | .1355 |
| 1750. | 4.6388 | 7.7522 | .87140 | 1203.77 | 1.05325 | .3030 |
| 1750. | 4.0000 | 9.1596 | .88781 | 1213.73 | 1.06438 | .2804 |
| 1750. | 3.0000 | 12.5793 | .91446 | 1229.71 | 1.08478 | .2435 |
| 1750. | 2.0000 | 19.4403 | .94214 | 1246.07 | 1.11133 | .2052 |
| 1750. | 1.0000 | 40.0597 | .97071 | 1262.73 | 1.15260 | .1662 |
| 1750. | .8000 | 50.3741 | .97652 | 1266.09 | 1.16515 | .1583 |
| 1750. | .6000 | 67.5666 | .98235 | 1269.45 | 1.18099 | .1505 |
| 1750. | .4000 | 101.9543 | .98821 | 1272.82 | 1.20281 | .1426 |
| 1750. | .2000 | 205.1226 | .99409 | 1276.20 | 1.23925 | .1348 |
| 1775. | 5.0694 | 7.1468 | .86809 | 1204.93 | 1.04985 | .3028 |
| 1775. | 5.0000 | 7.2596 | .86973 | 1205.93 | 1.05090 | .3006 |
| 1775. | 4.0000 | 9.3269 | .89392 | 1220.59 | 1.06746 | .2683 |
| 1775. | 3.0000 | 12.7871 | .91916 | 1235.68 | 1.08747 | .2343 |
| 1775. | 2.0000 | 19.7270 | .94534 | 1251.12 | 1.11360 | .1990 |
| 1775. | 1.0000 | 40.5807 | .97234 | 1266.84 | 1.15445 | .1631 |
| 1775. | .8000 | 51.0119 | .97782 | 1270.01 | 1.16692 | .1559 |
| 1775. | .6000 | 68.3991 | .98333 | 1273.19 | 1.18267 | .1487 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 1775. | .4000 | 103.1760 | .98886 | 1276.37 | 1.20441 | .1414 |
| 1775. | .2000 | 207.5116 | .99442 | 1279.56 | 1.24077 | .1342 |
| 1800. | 5.5287 | 6.6014 | .86482 | 1206.11 | 1.04655 | .3024 |
| 1800. | 5.0000 | 7.3986 | .87657 | 1213.27 | 1.05417 | .2873 |
| 1800. | 4.0000 | 9.4908 | .89956 | 1227.16 | 1.07039 | .2574 |
| 1800. | 3.0000 | 12.9912 | .92350 | 1241.43 | 1.09003 | .2260 |
| 1800. | 2.0000 | 20.0101 | .94830 | 1256.03 | 1.11578 | .1935 |
| 1800. | 1.0000 | 41.0980 | .97384 | 1270.89 | 1.15625 | .1604 |
| 1800. | .8000 | 51.6461 | .97902 | 1273.88 | 1.16864 | .1537 |
| 1800. | .6000 | 69.2279 | .98423 | 1276.89 | 1.18432 | .1470 |
| 1800. | .4000 | 104.3940 | .98947 | 1279.90 | 1.20598 | .1404 |
| 1800. | .2000 | 209.8969 | .99472 | 1282.91 | 1.24226 | .1337 |
| 1825. | 6.0179 | 6.1090 | .86159 | 1207.32 | 1.04337 | .3019 |
| 1825. | 6.0000 | 6.1298 | .86196 | 1207.54 | 1.04360 | .3014 |
| 1825. | 5.0000 | 7.5346 | .88292 | 1220.30 | 1.05727 | .2753 |
| 1825. | 4.0000 | 9.6516 | .90479 | 1233.47 | 1.07316 | .2476 |
| 1825. | 3.0000 | 13.1922 | .92752 | 1246.99 | 1.09248 | .2185 |
| 1825. | 2.0000 | 20.2898 | .95103 | 1260.80 | 1.11789 | .1885 |
| 1825. | 1.0000 | 41.6119 | .97523 | 1274.86 | 1.15800 | .1579 |
| 1825. | .8000 | 52.2768 | .98014 | 1277.70 | 1.17032 | .1517 |
| 1825. | .6000 | 70.0533 | .98507 | 1280.54 | 1.18593 | .1455 |
| 1825. | .4000 | 105.6086 | .99003 | 1283.39 | 1.20752 | .1394 |
| 1825. | .2000 | 212.2789 | .99500 | 1286.25 | 1.24373 | .1332 |
| 1850. | 6.5378 | 5.6636 | .85839 | 1208.55 | 1.04028 | .3012 |
| 1850. | 6.0000 | 6.2461 | .86881 | 1214.91 | 1.04681 | .2887 |
| 1850. | 5.0000 | 7.6680 | .88881 | 1227.05 | 1.06020 | .2644 |
| 1850. | 4.0000 | 9.8096 | .90964 | 1239.54 | 1.07581 | .2387 |
| 1850. | 3.0000 | 13.3901 | .93125 | 1252.36 | 1.09482 | .2117 |
| 1850. | 2.0000 | 20.5665 | .95357 | 1265.46 | 1.11991 | .1840 |
| 1850. | 1.0000 | 42.1227 | .97651 | 1278.78 | 1.15970 | .1556 |
| 1850. | .8000 | 52.9045 | .98117 | 1281.47 | 1.17196 | .1499 |
| 1850. | .6000 | 70.8756 | .98585 | 1284.16 | 1.18750 | .1442 |
| 1850. | .4000 | 106.8201 | .99055 | 1286.86 | 1.20903 | .1385 |
| 1850. | .2000 | 214.6577 | .99526 | 1289.57 | 1.24517 | .1327 |
| 1875. | 7.0897 | 5.2598 | .85523 | 1209.80 | 1.03730 | .3004 |
| 1875. | 7.0000 | 5.3372 | .85684 | 1210.79 | 1.03828 | .2985 |
| 1875. | 6.0000 | 6.3601 | .87519 | 1221.99 | 1.04985 | .2772 |
| 1875. | 5.0000 | 7.7988 | .89430 | 1233.53 | 1.06299 | .2545 |
| 1875. | 4.0000 | 9.9649 | .91415 | 1245.41 | 1.07833 | .2306 |
| 1875. | 3.0000 | 13.5853 | .93471 | 1257.58 | 1.09706 | .2056 |
| 1875. | 2.0000 | 20.8403 | .95592 | 1270.01 | 1.12187 | .1798 |
| 1875. | 1.0000 | 42.6306 | .97770 | 1282.65 | 1.16137 | .1536 |
| 1875. | .8000 | 53.5293 | .98213 | 1285.20 | 1.17357 | .1483 |
| 1875. | .6000 | 71.6950 | .98657 | 1287.75 | 1.18905 | .1430 |
| 1875. | .4000 | 108.0287 | .99103 | 1290.32 | 1.21052 | .1377 |
| 1875. | .2000 | 217.0336 | .99550 | 1292.88 | 1.24660 | .1323 |
| 1900. | 7.6745 | 4.8931 | .85210 | 1211.09 | 1.03441 | .2994 |
| 1900. | 7.0000 | 5.4367 | .86357 | 1218.10 | 1.04139 | .2867 |
| 1900. | 6.0000 | 6.4719 | .88114 | 1228.78 | 1.05275 | .2667 |
| 1900. | 5.0000 | 7.9273 | .89940 | 1239.78 | 1.06566 | .2455 |
| 1900. | 4.0000 | 10.1178 | .91834 | 1251.08 | 1.08075 | .2232 |
| 1900. | 3.0000 | 13.7780 | .93792 | 1262.65 | 1.09922 | .2000 |
| 1900. | 2.0000 | 21.1116 | .95810 | 1274.45 | 1.12376 | .1761 |
| 1900. | 1.0000 | 43.1360 | .97881 | 1286.46 | 1.16299 | .1517 |
| 1900. | .8000 | 54.1514 | .98302 | 1288.88 | 1.17514 | .1468 |
| 1900. | .6000 | 72.5119 | .98724 | 1291.31 | 1.19057 | .1419 |
| 1900. | .4000 | 109.2347 | .99147 | 1293.75 | 1.21198 | .1369 |
| 1900. | .2000 | 219.4070 | .99573 | 1296.19 | 1.24801 | .1320 |
| 1925. | 8.2932 | 4.5593 | .84899 | 1212.39 | 1.03161 | .2984 |
| 1925. | 8.0000 | 4.7523 | .85364 | 1215.24 | 1.03436 | .2934 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 1925. | 7.0000 | 5.5344 | .86986 | 1225.13 | 1.04435 | .2758 |
| 1925. | 6.0000 | 6.5818 | .88670 | 1235.33 | 1.05551 | .2571 |
| 1925. | 5.0000 | 8.0537 | .90416 | 1245.81 | 1.06820 | .2373 |
| 1925. | 4.0000 | 10.2684 | .92225 | 1256.57 | 1.08307 | .2165 |
| 1925. | 3.0000 | 13.9684 | .94092 | 1267.58 | 1.10130 | .1949 |
| 1925. | 2.0000 | 21.3805 | .96013 | 1278.81 | 1.12560 | .1727 |
| 1925. | 1.0000 | 43.6389 | .97985 | 1290.23 | 1.16458 | .1500 |
| 1925. | .8000 | 54.7712 | .98384 | 1292.54 | 1.17668 | .1454 |
| 1925. | .6000 | 73.3263 | .98786 | 1294.85 | 1.19206 | .1408 |
| 1925. | .4000 | 110.4383 | .99189 | 1297.16 | 1.21342 | .1362 |
| 1925. | .2000 | 221.7779 | .99594 | 1299.48 | 1.24940 | .1316 |
| 1950. | 8.9469 | 4.2550 | .84591 | 1213.72 | 1.02890 | .2973 |
| 1950. | 8.0000 | 4.8388 | .86017 | 1222.44 | 1.03736 | .2825 |
| 1950. | 7.0000 | 5.6303 | .87575 | 1231.90 | 1.04718 | .2659 |
| 1950. | 6.0000 | 6.6897 | .89189 | 1241.64 | 1.05814 | .2483 |
| 1950. | 5.0000 | 8.1781 | .90861 | 1251.65 | 1.07063 | .2298 |
| 1950. | 4.0000 | 10.4171 | .92589 | 1261.91 | 1.08529 | .2104 |
| 1950. | 3.0000 | 14.1567 | .94371 | 1272.40 | 1.10331 | .1903 |
| 1950. | 2.0000 | 21.6473 | .96203 | 1283.09 | 1.12739 | .1696 |
| 1950. | 1.0000 | 44.1397 | .98081 | 1293.96 | 1.16614 | .1484 |
| 1950. | .8000 | 55.3888 | .98461 | 1296.16 | 1.17819 | .1442 |
| 1950. | .6000 | 74.1385 | .98844 | 1298.35 | 1.19352 | .1399 |
| 1950. | .4000 | 111.6397 | .99228 | 1300.56 | 1.21484 | .1356 |
| 1950. | .2000 | 224.1466 | .99613 | 1302.77 | 1.25077 | .1313 |
| 1975. | 9.6366 | 3.9770 | .84284 | 1215.08 | 1.02627 | .2962 |
| 1975. | 9.0000 | 4.3036 | .85182 | 1220.56 | 1.03146 | .2872 |
| 1975. | 8.0000 | 4.9239 | .86630 | 1229.37 | 1.04022 | .2724 |
| 1975. | 7.0000 | 5.7245 | .88127 | 1238.43 | 1.04987 | .2567 |
| 1975. | 6.0000 | 6.7959 | .89675 | 1247.75 | 1.06066 | .2402 |
| 1975. | 5.0000 | 8.3007 | .91276 | 1257.31 | 1.07297 | .2229 |
| 1975. | 4.0000 | 10.5638 | .92929 | 1267.10 | 1.08743 | .2048 |
| 1975. | 3.0000 | 14.3430 | .94631 | 1277.10 | 1.10525 | .1860 |
| 1975. | 2.0000 | 21.9120 | .96379 | 1287.29 | 1.12912 | .1667 |
| 1975. | 1.0000 | 44.6384 | .98170 | 1297.65 | 1.16766 | .1470 |
| 1975. | .8000 | 56.0043 | .98533 | 1299.74 | 1.17967 | .1430 |
| 1975. | .6000 | 74.9487 | .98898 | 1301.84 | 1.19496 | .1390 |
| 1975. | .4000 | 112.8390 | .99264 | 1303.94 | 1.21623 | .1350 |
| 1975. | .2000 | 226.5133 | .99631 | 1306.05 | 1.25212 | .1310 |
| 2000. | 10.3632 | 3.7226 | .83979 | 1216.45 | 1.02373 | .2950 |
| 2000. | 10.0000 | 3.8799 | .84460 | 1219.38 | 1.02644 | .2903 |
| 2000. | 9.0000 | 4.3800 | .85812 | 1227.61 | 1.03435 | .2770 |
| 2000. | 8.0000 | 5.0075 | .87205 | 1236.06 | 1.04296 | .2631 |
| 2000. | 7.0000 | 5.8172 | .88644 | 1244.74 | 1.05245 | .2484 |
| 2000. | 6.0000 | 6.9006 | .90131 | 1253.66 | 1.06308 | .2329 |
| 2000. | 5.0000 | 8.4217 | .91665 | 1262.80 | 1.07521 | .2166 |
| 2000. | 4.0000 | 10.7088 | .93247 | 1272.15 | 1.08950 | .1997 |
| 2000. | 3.0000 | 14.5276 | .94874 | 1281.70 | 1.10713 | .1821 |
| 2000. | 2.0000 | 22.1749 | .96544 | 1291.43 | 1.13081 | .1641 |
| 2000. | 1.0000 | 45.1353 | .98254 | 1301.31 | 1.16916 | .1457 |
| 2000. | .8000 | 56.6180 | .98601 | 1303.31 | 1.18113 | .1420 |
| 2000. | .6000 | 75.7569 | .98948 | 1305.31 | 1.19638 | .1383 |
| 2000. | .4000 | 114.0364 | .99298 | 1307.31 | 1.21761 | .1345 |
| 2000. | .2000 | 228.8781 | .99648 | 1309.32 | 1.25346 | .1308 |
| 2025. | 11.1276 | 3.4893 | .83673 | 1217.83 | 1.02126 | .2939 |
| 2025. | 11.0000 | 3.5365 | .83833 | 1218.81 | 1.02214 | .2924 |
| 2025. | 10.0000 | 3.9490 | .85101 | 1226.51 | 1.02933 | .2803 |
| 2025. | 9.0000 | 4.4550 | .86404 | 1234.42 | 1.03710 | .2677 |
| 2025. | 8.0000 | 5.0897 | .87746 | 1242.53 | 1.04557 | .2545 |
| 2025. | 7.0000 | 5.9086 | .89130 | 1250.85 | 1.05493 | .2407 |
| 2025. | 6.0000 | 7.0037 | .90557 | 1259.39 | 1.06540 | .2261 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 2025. | 5.0000 | 8.5411 | .92029 | 1268.14 | 1.07738 | .2108 |
| 2025. | 4.0000 | 10.8522 | .93545 | 1277.08 | 1.09150 | .1950 |
| 2025. | 3.0000 | 14.7104 | .95102 | 1286.21 | 1.10896 | .1786 |
| 2025. | 2.0000 | 22.4361 | .96699 | 1295.50 | 1.13246 | .1617 |
| 2025. | 1.0000 | 45.6304 | .98333 | 1304.94 | 1.17063 | .1445 |
| 2025. | .8000 | 57.2299 | .98663 | 1306.84 | 1.18256 | .1410 |
| 2025. | .6000 | 76.5635 | .98996 | 1308.75 | 1.19777 | .1375 |
| 2025. | .4000 | 115.2321 | .99329 | 1310.67 | 1.21897 | .1340 |
| 2025. | .2000 | 231.2411 | .99664 | 1312.59 | 1.25478 | .1305 |
| 2050. | 11.9309 | 3.2751 | .83366 | 1219.23 | 1.01886 | .2928 |
| 2050. | 11.0000 | 3.5998 | .84481 | 1225.99 | 1.02501 | .2824 |
| 2050. | 10.0000 | 4.0171 | .85705 | 1233.40 | 1.03209 | .2710 |
| 2050. | 9.0000 | 4.5289 | .86961 | 1241.00 | 1.03974 | .2591 |
| 2050. | 8.0000 | 5.1707 | .88254 | 1248.79 | 1.04808 | .2467 |
| 2050. | 7.0000 | 5.9986 | .89586 | 1256.78 | 1.05730 | .2336 |
| 2050. | 6.0000 | 7.1055 | .90958 | 1264.97 | 1.06763 | .2199 |
| 2050. | 5.0000 | 8.6591 | .92371 | 1273.34 | 1.07946 | .2055 |
| 2050. | 4.0000 | 10.9941 | .93824 | 1281.90 | 1.09343 | .1907 |
| 2050. | 3.0000 | 14.8918 | .95315 | 1290.63 | 1.11073 | .1753 |
| 2050. | 2.0000 | 22.6958 | .96843 | 1299.51 | 1.13407 | .1595 |
| 2050. | 1.0000 | 46.1239 | .98406 | 1308.54 | 1.17207 | .1434 |
| 2050. | .8000 | 57.8402 | .98722 | 1310.36 | 1.18397 | .1401 |
| 2050. | .6000 | 77.3684 | .99040 | 1312.18 | 1.19914 | .1369 |
| 2050. | .4000 | 116.4262 | .99359 | 1314.01 | 1.22031 | .1336 |
| 2050. | .2000 | 233.6025 | .99679 | 1315.85 | 1.25609 | .1303 |
| 2075. | 12.7740 | 3.0780 | .83058 | 1220.64 | 1.01653 | .2917 |
| 2075. | 12.0000 | 3.3112 | .83938 | 1225.95 | 1.02128 | .2837 |
| 2075. | 11.0000 | 3.6619 | .85093 | 1232.93 | 1.02777 | .2732 |
| 2075. | 10.0000 | 4.0841 | .86275 | 1240.07 | 1.03473 | .2624 |
| 2075. | 9.0000 | 4.6016 | .87487 | 1247.38 | 1.04227 | .2512 |
| 2075. | 8.0000 | 5.2505 | .88733 | 1254.87 | 1.05049 | .2394 |
| 2075. | 7.0000 | 6.0873 | .90015 | 1262.54 | 1.05958 | .2270 |
| 2075. | 6.0000 | 7.2060 | .91335 | 1270.39 | 1.06978 | .2141 |
| 2075. | 5.0000 | 8.7757 | .92692 | 1278.42 | 1.08147 | .2007 |
| 2075. | 4.0000 | 11.1346 | .94086 | 1286.62 | 1.09530 | .1867 |
| 2075. | 3.0000 | 15.0717 | .95515 | 1294.97 | 1.11245 | .1723 |
| 2075. | 2.0000 | 22.9539 | .96979 | 1303.48 | 1.13564 | .1575 |
| 2075. | 1.0000 | 46.6159 | .98475 | 1312.11 | 1.17348 | .1424 |
| 2075. | .8000 | 58.4490 | .98777 | 1313.85 | 1.18535 | .1393 |
| 2075. | .6000 | 78.1718 | .99081 | 1315.60 | 1.20050 | .1363 |
| 2075. | .4000 | 117.6188 | .99386 | 1317.35 | 1.22163 | .1332 |
| 2075. | .2000 | 235.9624 | .99693 | 1319.10 | 1.25738 | .1301 |
| 2100. | 13.6577 | 2.8963 | .82747 | 1222.06 | 1.01427 | .2907 |
| 2100. | 13.0000 | 3.0691 | .83460 | 1226.33 | 1.01802 | .2843 |
| 2100. | 12.0000 | 3.3685 | .84555 | 1232.93 | 1.02402 | .2746 |
| 2100. | 11.0000 | 3.7232 | .85671 | 1239.65 | 1.03041 | .2647 |
| 2100. | 10.0000 | 4.1500 | .86812 | 1246.53 | 1.03727 | .2545 |
| 2100. | 9.0000 | 4.6733 | .87982 | 1253.56 | 1.04469 | .2438 |
| 2100. | 8.0000 | 5.3293 | .89184 | 1260.76 | 1.05281 | .2327 |
| 2100. | 7.0000 | 6.1750 | .90419 | 1268.14 | 1.06178 | .2210 |
| 2100. | 6.0000 | 7.3053 | .91689 | 1275.68 | 1.07186 | .2088 |
| 2100. | 5.0000 | 8.8911 | .92993 | 1283.38 | 1.08342 | .1962 |
| 2100. | 4.0000 | 11.2738 | .94332 | 1291.24 | 1.09711 | .1830 |
| 2100. | 3.0000 | 15.2503 | .95703 | 1299.25 | 1.11413 | .1695 |
| 2100. | 2.0000 | 23.2108 | .97106 | 1307.39 | 1.13717 | .1556 |
| 2100. | 1.0000 | 47.1065 | .98539 | 1315.66 | 1.17488 | .1415 |
| 2100. | .8000 | 59.0565 | .98829 | 1317.32 | 1.18671 | .1386 |
| 2100. | .6000 | 78.9739 | .99120 | 1319.00 | 1.20183 | .1357 |
| 2100. | .4000 | 118.8100 | .99412 | 1320.67 | 1.22294 | .1328 |
| 2100. | .2000 | 238.3209 | .99706 | 1322.35 | 1.25865 | .1299 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 2125. | 14.5829 | 2.7287 | .82432 | 1223.47 | 1.01207 | .2898 |
| 2125. | 14.0000 | 2.8631 | .83037 | 1227.08 | 1.01518 | .2845 |
| 2125. | 13.0000 | 3.1221 | .84081 | 1233.33 | 1.02074 | .2754 |
| 2125. | 12.0000 | 3.4248 | .85139 | 1239.69 | 1.02664 | .2662 |
| 2125. | 11.0000 | 3.7835 | .86217 | 1246.17 | 1.03294 | .2568 |
| 2125. | 10.0000 | 4.2151 | .87320 | 1252.80 | 1.03971 | .2471 |
| 2125. | 9.0000 | 4.7440 | .88450 | 1259.57 | 1.04703 | .2370 |
| 2125. | 8.0000 | 5.4070 | .89609 | 1266.50 | 1.05504 | .2265 |
| 2125. | 7.0000 | 6.2615 | .90800 | 1273.59 | 1.06390 | .2154 |
| 2125. | 6.0000 | 7.4035 | .92022 | 1280.83 | 1.07386 | .2040 |
| 2125. | 5.0000 | 9.0053 | .93277 | 1288.23 | 1.08531 | .1920 |
| 2125. | 4.0000 | 11.4118 | .94563 | 1295.77 | 1.09887 | .1797 |
| 2125. | 3.0000 | 15.4276 | .95880 | 1303.45 | 1.11576 | .1670 |
| 2125. | 2.0000 | 23.4663 | .97226 | 1311.26 | 1.13868 | .1539 |
| 2125. | 1.0000 | 47.5959 | .98600 | 1319.18 | 1.17625 | .1406 |
| 2125. | .8000 | 59.6626 | .98878 | 1320.78 | 1.18806 | .1379 |
| 2125. | .6000 | 79.7746 | .99157 | 1322.38 | 1.20315 | .1352 |
| 2125. | .4000 | 119.9999 | .99437 | 1323.99 | 1.22422 | .1325 |
| 2125. | .2000 | 240.6781 | .99718 | 1325.60 | 1.25991 | .1298 |
| 2150. | 15.5504 | 2.5736 | .82112 | 1224.88 | 1.00993 | .2891 |
| 2150. | 15.0000 | 2.6858 | .82660 | 1228.13 | 1.01268 | .2843 |
| 2150. | 14.0000 | 2.9125 | .83659 | 1234.08 | 1.01787 | .2756 |
| 2150. | 13.0000 | 3.1743 | .84668 | 1240.11 | 1.02335 | .2671 |
| 2150. | 12.0000 | 3.4804 | .85691 | 1246.24 | 1.02917 | .2584 |
| 2150. | 11.0000 | 3.8430 | .86734 | 1252.50 | 1.03538 | .2495 |
| 2150. | 10.0000 | 4.2792 | .87800 | 1258.89 | 1.04205 | .2403 |
| 2150. | 9.0000 | 4.8138 | .88891 | 1265.42 | 1.04928 | .2307 |
| 2150. | 8.0000 | 5.4837 | .90011 | 1272.09 | 1.05719 | .2207 |
| 2150. | 7.0000 | 6.3471 | .91159 | 1278.91 | 1.06595 | .2103 |
| 2150. | 6.0000 | 7.5006 | .92337 | 1285.88 | 1.07580 | .1994 |
| 2150. | 5.0000 | 9.1184 | .93544 | 1292.98 | 1.08714 | .1882 |
| 2150. | 4.0000 | 11.5487 | .94781 | 1300.22 | 1.10059 | .1766 |
| 2150. | 3.0000 | 15.6038 | .96046 | 1307.59 | 1.11736 | .1646 |
| 2150. | 2.0000 | 23.7207 | .97338 | 1315.08 | 1.14015 | .1523 |
| 2150. | 1.0000 | 48.0840 | .98657 | 1322.69 | 1.17760 | .1398 |
| 2150. | .8000 | 60.2675 | .98924 | 1324.22 | 1.18938 | .1373 |
| 2150. | .6000 | 80.5741 | .99191 | 1325.76 | 1.20445 | .1347 |
| 2150. | .4000 | 121.1885 | .99460 | 1327.30 | 1.22550 | .1322 |
| 2150. | .2000 | 243.0340 | .99729 | 1328.84 | 1.26116 | .1296 |
| 2175. | 16.5612 | 2.4299 | .81785 | 1226.28 | 1.00784 | .2886 |
| 2175. | 16.0000 | 2.5318 | .82324 | 1229.45 | 1.01048 | .2838 |
| 2175. | 15.0000 | 2.7320 | .83284 | 1235.12 | 1.01535 | .2756 |
| 2175. | 14.0000 | 2.9611 | .84249 | 1240.86 | 1.02046 | .2675 |
| 2175. | 13.0000 | 3.2258 | .85224 | 1246.69 | 1.02586 | .2594 |
| 2175. | 12.0000 | 3.5352 | .86214 | 1252.61 | 1.03160 | .2511 |
| 2175. | 11.0000 | 3.9017 | .87223 | 1258.65 | 1.03772 | .2427 |
| 2175. | 10.0000 | 4.3426 | .88254 | 1264.81 | 1.04431 | .2339 |
| 2175. | 9.0000 | 4.8828 | .89309 | 1271.11 | 1.05145 | .2248 |
| 2175. | 8.0000 | 5.5596 | .90390 | 1277.54 | 1.05927 | .2154 |
| 2175. | 7.0000 | 6.4317 | .91498 | 1284.11 | 1.06793 | .2055 |
| 2175. | 6.0000 | 7.5968 | .92633 | 1290.81 | 1.07768 | .1953 |
| 2175. | 5.0000 | 9.2305 | .93796 | 1297.64 | 1.08891 | .1846 |
| 2175. | 4.0000 | 11.6846 | .94986 | 1304.60 | 1.10226 | .1737 |
| 2175. | 3.0000 | 15.7789 | .96202 | 1311.68 | 1.11892 | .1624 |
| 2175. | 2.0000 | 23.9740 | .97444 | 1318.87 | 1.14160 | .1508 |
| 2175. | 1.0000 | 48.5711 | .98711 | 1326.17 | 1.17893 | .1391 |
| 2175. | .8000 | 60.8714 | .98967 | 1327.64 | 1.19069 | .1367 |
| 2175. | .6000 | 81.3726 | .99224 | 1329.12 | 1.20573 | .1343 |
| 2175. | .4000 | 122.3761 | .99482 | 1330.60 | 1.22676 | .1319 |
| 2175. | .2000 | 245.3889 | .99740 | 1332.08 | 1.26240 | .1295 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 2200. | 17.6159 | 2.2967 | .81449 | 1227.65 | 1.00580 | .2883 |
| 2200. | 17.0000 | 2.3966 | .82022 | 1230.99 | 1.00853 | .2832 |
| 2200. | 16.0000 | 2.5752 | .82948 | 1236.43 | 1.01312 | .2752 |
| 2200. | 15.0000 | 2.7775 | .83875 | 1241.91 | 1.01791 | .2675 |
| 2200. | 14.0000 | 3.0090 | .84807 | 1247.45 | 1.02295 | .2599 |
| 2200. | 13.0000 | 3.2765 | .85751 | 1253.08 | 1.02828 | .2522 |
| 2200. | 12.0000 | 3.5892 | .86709 | 1258.80 | 1.03394 | .2444 |
| 2200. | 11.0000 | 3.9596 | .87686 | 1264.64 | 1.03998 | .2364 |
| 2200. | 10.0000 | 4.4051 | .88683 | 1270.59 | 1.04649 | .2280 |
| 2200. | 9.0000 | 4.9509 | .89704 | 1276.66 | 1.05355 | .2194 |
| 2200. | 8.0000 | 5.6346 | .90748 | 1282.86 | 1.06128 | .2104 |
| 2200. | 7.0000 | 6.5154 | .91818 | 1289.19 | 1.06985 | .2011 |
| 2200. | 6.0000 | 7.6920 | .92913 | 1295.64 | 1.07951 | .1914 |
| 2200. | 5.0000 | 9.3417 | .94033 | 1302.22 | 1.09064 | .1814 |
| 2200. | 4.0000 | 11.8194 | .95179 | 1308.91 | 1.10388 | .1710 |
| 2200. | 3.0000 | 15.9531 | .96350 | 1315.71 | 1.12044 | .1604 |
| 2200. | 2.0000 | 24.2262 | .97544 | 1322.63 | 1.14302 | .1495 |
| 2200. | 1.0000 | 49.0571 | .98761 | 1329.64 | 1.18024 | .1384 |
| 2200. | .8000 | 61.4741 | .99007 | 1331.05 | 1.19198 | .1361 |
| 2200. | .6000 | 82.1699 | .99254 | 1332.47 | 1.20700 | .1339 |
| 2200. | .4000 | 123.5626 | .99502 | 1333.89 | 1.22800 | .1316 |
| 2200. | .2000 | 247.7427 | .99751 | 1335.31 | 1.26362 | .1293 |
| 2225. | 18.7154 | 2.1728 | .81103 | 1229.00 | 1.00380 | .2883 |
| 2225. | 18.0000 | 2.2772 | .81750 | 1232.74 | 1.00681 | .2824 |
| 2225. | 17.0000 | 2.4376 | .82647 | 1237.96 | 1.01114 | .2746 |
| 2225. | 16.0000 | 2.6179 | .83539 | 1243.21 | 1.01566 | .2672 |
| 2225. | 15.0000 | 2.8223 | .84434 | 1248.50 | 1.02038 | .2600 |
| 2225. | 14.0000 | 3.0562 | .85337 | 1253.86 | 1.02535 | .2528 |
| 2225. | 13.0000 | 3.3266 | .86250 | 1259.30 | 1.03061 | .2455 |
| 2225. | 12.0000 | 3.6426 | .87179 | 1264.83 | 1.03619 | .2381 |
| 2225. | 11.0000 | 4.0168 | .88125 | 1270.47 | 1.04217 | .2305 |
| 2225. | 10.0000 | 4.4669 | .89091 | 1276.22 | 1.04860 | .2225 |
| 2225. | 9.0000 | 5.0183 | .90078 | 1282.08 | 1.05558 | .2143 |
| 2225. | 8.0000 | 5.7088 | .91087 | 1288.06 | 1.06323 | .2058 |
| 2225. | 7.0000 | 6.5984 | .92120 | 1294.16 | 1.07171 | .1970 |
| 2225. | 6.0000 | 7.7864 | .93177 | 1300.38 | 1.08128 | .1878 |
| 2225. | 5.0000 | 9.4520 | .94258 | 1306.71 | 1.09232 | .1783 |
| 2225. | 4.0000 | 11.9534 | .95362 | 1313.15 | 1.10547 | .1685 |
| 2225. | 3.0000 | 16.1263 | .96489 | 1319.70 | 1.12193 | .1585 |
| 2225. | 2.0000 | 24.4775 | .97638 | 1326.35 | 1.14441 | .1482 |
| 2225. | 1.0000 | 49.5421 | .98809 | 1333.09 | 1.18153 | .1377 |
| 2225. | .8000 | 62.0759 | .99045 | 1334.45 | 1.19325 | .1356 |
| 2225. | .6000 | 82.9663 | .99283 | 1335.81 | 1.20825 | .1335 |
| 2225. | .4000 | 124.7482 | .99521 | 1337.18 | 1.22923 | .1314 |
| 2225. | .2000 | 250.0955 | .99760 | 1338.55 | 1.26483 | .1292 |
| 2250. | 19.8605 | 2.0575 | .80745 | 1230.31 | 1.00185 | .2886 |
| 2250. | 19.0000 | 2.1709 | .81504 | 1234.66 | 1.00528 | .2815 |
| 2250. | 18.0000 | 2.3159 | .82374 | 1239.69 | 1.00939 | .2739 |
| 2250. | 17.0000 | 2.4778 | .83237 | 1244.73 | 1.01365 | .2668 |
| 2250. | 16.0000 | 2.6600 | .84100 | 1249.80 | 1.01810 | .2598 |
| 2250. | 15.0000 | 2.8665 | .84965 | 1254.91 | 1.02276 | .2530 |
| 2250. | 14.0000 | 3.1029 | .85839 | 1260.10 | 1.02766 | .2462 |
| 2250. | 13.0000 | 3.3760 | .86725 | 1265.36 | 1.03285 | .2393 |
| 2250. | 12.0000 | 3.6953 | .87625 | 1270.71 | 1.03837 | .2322 |
| 2250. | 11.0000 | 4.0734 | .88541 | 1276.16 | 1.04428 | .2250 |
| 2250. | 10.0000 | 4.5281 | .89477 | 1281.72 | 1.05064 | .2174 |
| 2250. | 9.0000 | 5.0849 | .90432 | 1287.38 | 1.05754 | .2096 |
| 2250. | 8.0000 | 5.7823 | .91409 | 1293.15 | 1.06511 | .2015 |
| 2250. | 7.0000 | 6.6805 | .92407 | 1299.04 | 1.07352 | .1931 |
| 2250. | 6.0000 | 7.8800 | .93427 | 1305.03 | 1.08301 | .1844 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 2250. | 5.0000 | 9.5615 | .94470 | 1311.13 | 1.09396 | .1755 |
| 2250. | 4.0000 | 12.0866 | .95534 | 1317.34 | 1.10702 | .1662 |
| 2250. | 3.0000 | 16.2986 | .96620 | 1323.64 | 1.12339 | .1568 |
| 2250. | 2.0000 | 24.7280 | .97727 | 1330.04 | 1.14578 | .1471 |
| 2250. | 1.0000 | 50.0262 | .98854 | 1336.52 | 1.18280 | .1372 |
| 2250. | .8000 | 62.6768 | .99082 | 1337.83 | 1.19450 | .1352 |
| 2250. | .6000 | 83.7618 | .99310 | 1339.14 | 1.20948 | .1331 |
| 2250. | .4000 | 125.9328 | .99539 | 1340.46 | 1.23045 | .1311 |
| 2250. | .2000 | 252.4475 | .99769 | 1341.77 | 1.26603 | .1291 |
| 2275. | 21.0517 | 1.9499 | .80372 | 1231.58 | .99993 | .2893 |
| 2275. | 21.0000 | 1.9558 | .80417 | 1231.84 | 1.00013 | .2888 |
| 2275. | 20.0000 | 2.0756 | .81281 | 1236.73 | 1.00392 | .2806 |
| 2275. | 19.0000 | 2.2077 | .82128 | 1241.59 | 1.00783 | .2731 |
| 2275. | 18.0000 | 2.3540 | .82965 | 1246.44 | 1.01187 | .2661 |
| 2275. | 17.0000 | 2.5175 | .83798 | 1251.30 | 1.01607 | .2595 |
| 2275. | 16.0000 | 2.7015 | .84631 | 1256.20 | 1.02045 | .2529 |
| 2275. | 15.0000 | 2.9101 | .85470 | 1261.15 | 1.02505 | .2465 |
| 2275. | 14.0000 | 3.1489 | .86317 | 1266.17 | 1.02990 | .2400 |
| 2275. | 13.0000 | 3.4249 | .87176 | 1271.27 | 1.03502 | .2335 |
| 2275. | 12.0000 | 3.7474 | .88048 | 1276.45 | 1.04048 | .2268 |
| 2275. | 11.0000 | 4.1293 | .88937 | 1281.72 | 1.04632 | .2198 |
| 2275. | 10.0000 | 4.5886 | .89843 | 1287.09 | 1.05261 | .2127 |
| 2275. | 9.0000 | 5.1509 | .90768 | 1292.56 | 1.05945 | .2052 |
| 2275. | 8.0000 | 5.8551 | .91713 | 1298.14 | 1.06695 | .1975 |
| 2275. | 7.0000 | 6.7619 | .92678 | 1303.82 | 1.07528 | .1896 |
| 2275. | 6.0000 | 7.9728 | .93664 | 1309.60 | 1.08469 | .1813 |
| 2275. | 5.0000 | 9.6702 | .94670 | 1315.48 | 1.09556 | .1728 |
| 2275. | 4.0000 | 12.2189 | .95697 | 1321.46 | 1.10854 | .1641 |
| 2275. | 3.0000 | 16.4701 | .96744 | 1327.54 | 1.12483 | .1551 |
| 2275. | 2.0000 | 24.9776 | .97811 | 1333.70 | 1.14712 | .1460 |
| 2275. | 1.0000 | 50.5095 | .98896 | 1339.95 | 1.18406 | .1366 |
| 2275. | .8000 | 63.2769 | .99116 | 1341.20 | 1.19574 | .1347 |
| 2275. | .6000 | 84.5565 | .99336 | 1342.47 | 1.21070 | .1328 |
| 2275. | .4000 | 127.1165 | .99556 | 1343.73 | 1.23165 | .1309 |
| 2275. | .2000 | 254.7985 | .99778 | 1345.00 | 1.26721 | .1290 |
| 2300. | 22.2899 | 1.8494 | .79982 | 1232.79 | .99804 | .2904 |
| 2300. | 22.0000 | 1.8796 | .80232 | 1234.18 | .99908 | .2878 |
| 2300. | 21.0000 | 1.9899 | .81078 | 1238.94 | 1.00271 | .2796 |
| 2300. | 20.0000 | 2.1107 | .81905 | 1243.64 | 1.00644 | .2722 |
| 2300. | 19.0000 | 2.2438 | .82718 | 1248.32 | 1.01028 | .2654 |
| 2300. | 18.0000 | 2.3916 | .83525 | 1253.00 | 1.01426 | .2589 |
| 2300. | 17.0000 | 2.5567 | .84330 | 1257.70 | 1.01840 | .2527 |
| 2300. | 16.0000 | 2.7425 | .85137 | 1262.45 | 1.02272 | .2465 |
| 2300. | 15.0000 | 2.9532 | .85950 | 1267.24 | 1.02727 | .2404 |
| 2300. | 14.0000 | 3.1944 | .86771 | 1272.10 | 1.03205 | .2343 |
| 2300. | 13.0000 | 3.4732 | .87604 | 1277.03 | 1.03712 | .2280 |
| 2300. | 12.0000 | 3.7990 | .88451 | 1282.05 | 1.04252 | .2216 |
| 2300. | 11.0000 | 4.1847 | .89312 | 1287.15 | 1.04830 | .2150 |
| 2300. | 10.0000 | 4.6484 | .90191 | 1292.35 | 1.05453 | .2082 |
| 2300. | 9.0000 | 5.2162 | .91087 | 1297.64 | 1.06130 | .2011 |
| 2300. | 8.0000 | 5.9272 | .92001 | 1303.03 | 1.06873 | .1938 |
| 2300. | 7.0000 | 6.8427 | .92935 | 1308.52 | 1.07699 | .1863 |
| 2300. | 6.0000 | 8.0650 | .93888 | 1314.10 | 1.08633 | .1784 |
| 2300. | 5.0000 | 9.7782 | .94860 | 1319.77 | 1.09712 | .1704 |
| 2300. | 4.0000 | 12.3505 | .95852 | 1325.54 | 1.11002 | .1621 |
| 2300. | 3.0000 | 16.6409 | .96862 | 1331.40 | 1.12623 | .1536 |
| 2300. | 2.0000 | 25.2264 | .97890 | 1337.33 | 1.14845 | .1450 |
| 2300. | 1.0000 | 50.9920 | .98937 | 1343.35 | 1.18530 | .1361 |
| 2300. | .8000 | 63.8762 | .99148 | 1344.57 | 1.19697 | .1343 |
| 2300. | .6000 | 85.3503 | .99360 | 1345.78 | 1.21191 | .1325 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 2300. | .4000 | 128.2995 | .99573 | 1347.00 | 1.23284 | .1307 |
| 2300. | .2000 | 257.1488 | .99786 | 1348.22 | 1.26839 | .1289 |
| 2325. | 23.5757 | 1.7553 | .79573 | 1233.93 | .99618 | .2921 |
| 2325. | 23.0000 | 1.8104 | .80064 | 1236.63 | .99816 | .2868 |
| 2325. | 22.0000 | 1.9123 | .80893 | 1241.26 | 1.00164 | .2787 |
| 2325. | 21.0000 | 2.0233 | .81701 | 1245.82 | 1.00520 | .2713 |
| 2325. | 20.0000 | 2.1451 | .82494 | 1250.35 | 1.00886 | .2646 |
| 2325. | 19.0000 | 2.2795 | .83277 | 1254.86 | 1.01264 | .2582 |
| 2325. | 18.0000 | 2.4286 | .84056 | 1259.39 | 1.01656 | .2522 |
| 2325. | 17.0000 | 2.5953 | .84835 | 1263.94 | 1.02065 | .2464 |
| 2325. | 16.0000 | 2.7829 | .85617 | 1268.53 | 1.02492 | .2406 |
| 2325. | 15.0000 | 2.9958 | .86406 | 1273.18 | 1.02941 | .2348 |
| 2325. | 14.0000 | 3.2394 | .87203 | 1277.89 | 1.03414 | .2289 |
| 2325. | 13.0000 | 3.5209 | .88012 | 1282.67 | 1.03916 | .2230 |
| 2325. | 12.0000 | 3.8500 | .88833 | 1287.53 | 1.04450 | .2169 |
| 2325. | 11.0000 | 4.2395 | .89669 | 1292.47 | 1.05022 | .2105 |
| 2325. | 10.0000 | 4.7077 | .90521 | 1297.50 | 1.05639 | .2040 |
| 2325. | 9.0000 | 5.2810 | .91390 | 1302.62 | 1.06309 | .1973 |
| 2325. | 8.0000 | 5.9987 | .92275 | 1307.83 | 1.07046 | .1904 |
| 2325. | 7.0000 | 6.9228 | .93179 | 1313.13 | 1.07865 | .1832 |
| 2325. | 6.0000 | 8.1565 | .94101 | 1318.52 | 1.08792 | .1758 |
| 2325. | 5.0000 | 9.8855 | .95040 | 1324.00 | 1.09865 | .1681 |
| 2325. | 4.0000 | 12.4814 | .95998 | 1329.57 | 1.11148 | .1603 |
| 2325. | 3.0000 | 16.8109 | .96973 | 1335.22 | 1.12761 | .1522 |
| 2325. | 2.0000 | 25.4745 | .97966 | 1340.95 | 1.14975 | .1440 |
| 2325. | 1.0000 | 51.4738 | .98975 | 1346.75 | 1.18652 | .1356 |
| 2325. | .8000 | 64.4747 | .99179 | 1347.92 | 1.19818 | .1339 |
| 2325. | .6000 | 86.1434 | .99383 | 1349.09 | 1.21311 | .1322 |
| 2325. | .4000 | 129.4817 | .99588 | 1350.27 | 1.23402 | .1305 |
| 2325. | .2000 | 259.4983 | .99794 | 1351.44 | 1.26955 | .1288 |
| 2350. | 24.9097 | 1.6671 | .79140 | 1234.98 | .99434 | .2943 |
| 2350. | 24.0000 | 1.7471 | .79909 | 1239.18 | .99734 | .2858 |
| 2350. | 23.0000 | 1.8417 | .80724 | 1243.69 | 1.00068 | .2776 |
| 2350. | 22.0000 | 1.9443 | .81515 | 1248.12 | 1.00409 | .2703 |
| 2350. | 21.0000 | 2.0562 | .82289 | 1252.51 | 1.00759 | .2637 |
| 2350. | 20.0000 | 2.1790 | .83052 | 1256.87 | 1.01119 | .2575 |
| 2350. | 19.0000 | 2.3146 | .83808 | 1261.24 | 1.01492 | .2516 |
| 2350. | 18.0000 | 2.4652 | .84562 | 1265.62 | 1.01879 | .2460 |
| 2350. | 17.0000 | 2.6335 | .85316 | 1270.02 | 1.02282 | .2405 |
| 2350. | 16.0000 | 2.8229 | .86075 | 1274.48 | 1.02704 | .2350 |
| 2350. | 15.0000 | 3.0379 | .86840 | 1278.98 | 1.03148 | .2295 |
| 2350. | 14.0000 | 3.2839 | .87615 | 1283.55 | 1.03617 | .2239 |
| 2350. | 13.0000 | 3.5682 | .88400 | 1288.18 | 1.04113 | .2182 |
| 2350. | 12.0000 | 3.9004 | .89197 | 1292.89 | 1.04642 | .2124 |
| 2350. | 11.0000 | 4.2937 | .90009 | 1297.68 | 1.05208 | .2064 |
| 2350. | 10.0000 | 4.7665 | .90835 | 1302.55 | 1.05819 | .2002 |
| 2350. | 9.0000 | 5.3452 | .91677 | 1307.51 | 1.06484 | .1937 |
| 2350. | 8.0000 | 6.0696 | .92535 | 1312.55 | 1.07215 | .1871 |
| 2350. | 7.0000 | 7.0023 | .93410 | 1317.67 | 1.08028 | .1803 |
| 2350. | 6.0000 | 8.2473 | .94302 | 1322.89 | 1.08948 | .1732 |
| 2350. | 5.0000 | 9.9922 | .95211 | 1328.18 | 1.10014 | .1660 |
| 2350. | 4.0000 | 12.6116 | .96137 | 1333.55 | 1.11290 | .1586 |
| 2350. | 3.0000 | 16.9803 | .97079 | 1339.01 | 1.12896 | .1509 |
| 2350. | 2.0000 | 25.7219 | .98037 | 1344.53 | 1.15103 | .1431 |
| 2350. | 1.0000 | 51.9548 | .99011 | 1350.13 | 1.18773 | .1352 |
| 2350. | .8000 | 65.0725 | .99207 | 1351.26 | 1.19937 | .1336 |
| 2350. | .6000 | 86.9358 | .99405 | 1352.39 | 1.21429 | .1320 |
| 2350. | .4000 | 130.6632 | .99603 | 1353.53 | 1.23519 | .1304 |
| 2350. | .2000 | 261.8471 | .99801 | 1354.66 | 1.27070 | .1288 |
| 2375. | 26.2926 | 1.5843 | .78681 | 1235.93 | .99251 | .2973 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 2375. | 26.0000 | 1.6072 | .78933 | 1237.28 | .99344 | .2943 |
| 2375. | 25.0000 | 1.6892 | .79768 | 1241.80 | .99661 | .2848 |
| 2375. | 24.0000 | 1.7773 | .80570 | 1246.21 | .99983 | .2766 |
| 2375. | 23.0000 | 1.8724 | .81346 | 1250.52 | 1.00310 | .2693 |
| 2375. | 22.0000 | 1.9757 | .82103 | 1254.78 | 1.00645 | .2628 |
| 2375. | 21.0000 | 2.0886 | .82847 | 1259.01 | 1.00989 | .2567 |
| 2375. | 20.0000 | 2.2124 | .83582 | 1263.23 | 1.01344 | .2510 |
| 2375. | 19.0000 | 2.3493 | .84313 | 1267.45 | 1.01712 | .2455 |
| 2375. | 18.0000 | 2.5012 | .85043 | 1271.69 | 1.02094 | .2402 |
| 2375. | 17.0000 | 2.6712 | .85774 | 1275.97 | 1.02493 | .2350 |
| 2375. | 16.0000 | 2.8625 | .86511 | 1280.28 | 1.02910 | .2298 |
| 2375. | 15.0000 | 3.0795 | .87254 | 1284.65 | 1.03349 | .2245 |
| 2375. | 14.0000 | 3.3280 | .88007 | 1289.08 | 1.03813 | .2192 |
| 2375. | 13.0000 | 3.6150 | .88769 | 1293.58 | 1.04304 | .2138 |
| 2375. | 12.0000 | 3.9504 | .89544 | 1298.15 | 1.04828 | .2082 |
| 2375. | 11.0000 | 4.3475 | .90332 | 1302.79 | 1.05389 | .2024 |
| 2375. | 10.0000 | 4.8247 | .91134 | 1307.51 | 1.05995 | .1965 |
| 2375. | 9.0000 | 5.4088 | .91951 | 1312.31 | 1.06654 | .1904 |
| 2375. | 8.0000 | 6.1400 | .92783 | 1317.19 | 1.07379 | .1841 |
| 2375. | 7.0000 | 7.0812 | .93630 | 1322.15 | 1.08186 | .1776 |
| 2375. | 6.0000 | 8.3376 | .94494 | 1327.19 | 1.09101 | .1709 |
| 2375. | 5.0000 | 10.0982 | .95373 | 1332.30 | 1.10160 | .1640 |
| 2375. | 4.0000 | 12.7413 | .96268 | 1337.50 | 1.11430 | .1569 |
| 2375. | 3.0000 | 17.1490 | .97179 | 1342.76 | 1.13030 | .1497 |
| 2375. | 2.0000 | 25.9686 | .98104 | 1348.10 | 1.15230 | .1423 |
| 2375. | 1.0000 | 52.4352 | .99045 | 1353.51 | 1.18893 | .1348 |
| 2375. | .8000 | 65.6696 | .99235 | 1354.60 | 1.20055 | .1333 |
| 2375. | .6000 | 87.7275 | .99425 | 1355.69 | 1.21545 | .1318 |
| 2375. | .4000 | 131.8441 | .99616 | 1356.78 | 1.23634 | .1302 |
| 2375. | .2000 | 264.1952 | .99808 | 1357.88 | 1.27184 | .1287 |
| 2400. | 27.7249 | 1.5062 | .78190 | 1236.76 | .99069 | .3012 |
| 2400. | 27.0000 | 1.5590 | .78815 | 1240.07 | .99291 | .2933 |
| 2400. | 26.0000 | 1.6359 | .79639 | 1244.50 | .99597 | .2838 |
| 2400. | 25.0000 | 1.7182 | .80429 | 1248.81 | .99907 | .2756 |
| 2400. | 24.0000 | 1.8068 | .81191 | 1253.02 | 1.00222 | .2683 |
| 2400. | 23.0000 | 1.9025 | .81932 | 1257.16 | 1.00543 | .2618 |
| 2400. | 22.0000 | 2.0066 | .82659 | 1261.26 | 1.00873 | .2558 |
| 2400. | 21.0000 | 2.1204 | .83376 | 1265.34 | 1.01211 | .2502 |
| 2400. | 20.0000 | 2.2454 | .84086 | 1269.42 | 1.01562 | .2449 |
| 2400. | 19.0000 | 2.3835 | .84793 | 1273.51 | 1.01925 | .2398 |
| 2400. | 18.0000 | 2.5369 | .85501 | 1277.63 | 1.02302 | .2348 |
| 2400. | 17.0000 | 2.7084 | .86211 | 1281.77 | 1.02697 | .2298 |
| 2400. | 16.0000 | 2.9016 | .86927 | 1285.97 | 1.03110 | .2249 |
| 2400. | 15.0000 | 3.1208 | .87649 | 1290.21 | 1.03544 | .2199 |
| 2400. | 14.0000 | 3.3716 | .88380 | 1294.51 | 1.04003 | .2148 |
| 2400. | 13.0000 | 3.6614 | .89122 | 1298.87 | 1.04490 | .2096 |
| 2400. | 12.0000 | 4.0000 | .89874 | 1303.30 | 1.05009 | .2042 |
| 2400. | 11.0000 | 4.4008 | .90640 | 1307.80 | 1.05565 | .1988 |
| 2400. | 10.0000 | 4.8824 | .91418 | 1312.38 | 1.06166 | .1931 |
| 2400. | 9.0000 | 5.4720 | .92211 | 1317.03 | 1.06820 | .1873 |
| 2400. | 8.0000 | 6.2098 | .93018 | 1321.75 | 1.07539 | .1813 |
| 2400. | 7.0000 | 7.1596 | .93839 | 1326.55 | 1.08341 | .1751 |
| 2400. | 6.0000 | 8.4273 | .94676 | 1331.43 | 1.09250 | .1687 |
| 2400. | 5.0000 | 10.2037 | .95527 | 1336.38 | 1.10304 | .1622 |
| 2400. | 4.0000 | 12.8703 | .96393 | 1341.40 | 1.11567 | .1554 |
| 2400. | 3.0000 | 17.3172 | .97274 | 1346.49 | 1.13161 | .1486 |
| 2400. | 2.0000 | 26.2148 | .98169 | 1351.65 | 1.15354 | .1416 |
| 2400. | 1.0000 | 52.9150 | .99078 | 1356.87 | 1.19011 | .1344 |
| 2400. | .8000 | 66.2662 | .99261 | 1357.93 | 1.20172 | .1330 |
| 2400. | .6000 | 88.5186 | .99445 | 1358.98 | 1.21661 | .1315 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 2400. | .4000 | 133.0243 | .99629 | 1360.04 | 1.23748 | .1301 |
| 2400. | .2000 | 266.5427 | .99814 | 1361.10 | 1.27297 | .1286 |
| 2425. | 29.2072 | 1.4325 | .77663 | 1237.44 | .98886 | .3062 |
| 2425. | 29.0000 | 1.4462 | .77848 | 1238.40 | .98948 | .3036 |
| 2425. | 28.0000 | 1.5144 | .78708 | 1242.93 | .99244 | .2923 |
| 2425. | 27.0000 | 1.5867 | .79522 | 1247.27 | .99541 | .2828 |
| 2425. | 26.0000 | 1.6639 | .80299 | 1251.48 | .99840 | .2746 |
| 2425. | 25.0000 | 1.7466 | .81049 | 1255.59 | 1.00143 | .2673 |
| 2425. | 24.0000 | 1.8357 | .81776 | 1259.63 | 1.00452 | .2608 |
| 2425. | 23.0000 | 1.9322 | .82487 | 1263.62 | 1.00768 | .2549 |
| 2425. | 22.0000 | 2.0371 | .83187 | 1267.57 | 1.01092 | .2494 |
| 2425. | 21.0000 | 2.1519 | .83878 | 1271.52 | 1.01427 | .2442 |
| 2425. | 20.0000 | 2.2780 | .84565 | 1275.47 | 1.01772 | .2392 |
| 2425. | 19.0000 | 2.4173 | .85251 | 1279.44 | 1.02131 | .2344 |
| 2425. | 18.0000 | 2.5721 | .85938 | 1283.43 | 1.02504 | .2297 |
| 2425. | 17.0000 | 2.7453 | .86628 | 1287.46 | 1.02895 | .2250 |
| 2425. | 16.0000 | 2.9403 | .87323 | 1291.53 | 1.03304 | .2203 |
| 2425. | 15.0000 | 3.1616 | .88026 | 1295.65 | 1.03734 | .2155 |
| 2425. | 14.0000 | 3.4147 | .88737 | 1299.82 | 1.04188 | .2106 |
| 2425. | 13.0000 | 3.7073 | .89458 | 1304.06 | 1.04671 | .2057 |
| 2425. | 12.0000 | 4.0491 | .90189 | 1308.36 | 1.05185 | .2006 |
| 2425. | 11.0000 | 4.4536 | .90933 | 1312.73 | 1.05737 | .1953 |
| 2425. | 10.0000 | 4.9397 | .91689 | 1317.17 | 1.06333 | .1899 |
| 2425. | 9.0000 | 5.5346 | .92459 | 1321.67 | 1.06982 | .1843 |
| 2425. | 8.0000 | 6.2792 | .93241 | 1326.25 | 1.07696 | .1786 |
| 2425. | 7.0000 | 7.2375 | .94038 | 1330.90 | 1.08492 | .1727 |
| 2425. | 6.0000 | 8.5165 | .94849 | 1335.62 | 1.09396 | .1667 |
| 2425. | 5.0000 | 10.3087 | .95673 | 1340.41 | 1.10444 | .1604 |
| 2425. | 4.0000 | 12.9988 | .96512 | 1345.27 | 1.11702 | .1540 |
| 2425. | 3.0000 | 17.4848 | .97364 | 1350.19 | 1.13289 | .1475 |
| 2425. | 2.0000 | 26.4603 | .98230 | 1355.18 | 1.15477 | .1409 |
| 2425. | 1.0000 | 53.3942 | .99108 | 1360.23 | 1.19128 | .1341 |
| 2425. | .8000 | 66.8621 | .99286 | 1361.25 | 1.20288 | .1327 |
| 2425. | .6000 | 89.3092 | .99463 | 1362.26 | 1.21775 | .1313 |
| 2425. | .4000 | 134.2039 | .99642 | 1363.29 | 1.23861 | .1299 |
| 2425. | .2000 | 268.8896 | .99821 | 1364.31 | 1.27409 | .1286 |
| 2450. | 30.7400 | 1.3628 | .77093 | 1237.94 | .98703 | .3125 |
| 2450. | 30.0000 | 1.4085 | .77760 | 1241.39 | .98917 | .3027 |
| 2450. | 29.0000 | 1.4730 | .78611 | 1245.84 | .99205 | .2913 |
| 2450. | 28.0000 | 1.5413 | .79415 | 1250.10 | .99492 | .2818 |
| 2450. | 27.0000 | 1.6138 | .80181 | 1254.22 | .99781 | .2735 |
| 2450. | 26.0000 | 1.6912 | .80919 | 1258.24 | 1.00074 | .2663 |
| 2450. | 25.0000 | 1.7744 | .81633 | 1262.18 | 1.00371 | .2598 |
| 2450. | 24.0000 | 1.8641 | .82330 | 1266.06 | 1.00674 | .2539 |
| 2450. | 23.0000 | 1.9613 | .83013 | 1269.91 | 1.00985 | .2485 |
| 2450. | 22.0000 | 2.0671 | .83688 | 1273.73 | 1.01305 | .2434 |
| 2450. | 21.0000 | 2.1829 | .84357 | 1277.56 | 1.01635 | .2386 |
| 2450. | 20.0000 | 2.3101 | .85022 | 1281.39 | 1.01976 | .2340 |
| 2450. | 19.0000 | 2.4507 | .85687 | 1285.23 | 1.02331 | .2294 |
| 2450. | 18.0000 | 2.6070 | .86355 | 1289.11 | 1.02701 | .2249 |
| 2450. | 17.0000 | 2.7818 | .87025 | 1293.02 | 1.03087 | .2204 |
| 2450. | 16.0000 | 2.9786 | .87702 | 1296.98 | 1.03492 | .2159 |
| 2450. | 15.0000 | 3.2020 | .88385 | 1300.98 | 1.03918 | .2114 |
| 2450. | 14.0000 | 3.4576 | .89077 | 1305.04 | 1.04368 | .2067 |
| 2450. | 13.0000 | 3.7528 | .89778 | 1309.15 | 1.04847 | .2020 |
| 2450. | 12.0000 | 4.0978 | .90490 | 1313.33 | 1.05357 | .1971 |
| 2450. | 11.0000 | 4.5060 | .91213 | 1317.57 | 1.05904 | .1921 |
| 2450. | 10.0000 | 4.9966 | .91948 | 1321.87 | 1.06495 | .1869 |
| 2450. | 9.0000 | 5.5968 | .92695 | 1326.25 | 1.07140 | .1816 |
| 2450. | 8.0000 | 6.3481 | .93455 | 1330.68 | 1.07849 | .1761 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 2450. | 7.0000 | 7.3149 | .94227 | 1335.19 | 1.08640 | .1705 |
| 2450. | 6.0000 | 8.6053 | .95013 | 1339.76 | 1.09539 | .1647 |
| 2450. | 5.0000 | 10.4132 | .95812 | 1344.40 | 1.10582 | .1588 |
| 2450. | 4.0000 | 13.1268 | .96625 | 1349.10 | 1.11834 | .1527 |
| 2450. | 3.0000 | 17.6518 | .97450 | 1353.87 | 1.13416 | .1465 |
| 2450. | 2.0000 | 26.7054 | .98287 | 1358.69 | 1.15598 | .1402 |
| 2450. | 1.0000 | 53.8728 | .99138 | 1363.57 | 1.19244 | .1337 |
| 2450. | .8000 | 67.4575 | .99309 | 1364.56 | 1.20402 | .1324 |
| 2450. | .6000 | 90.0991 | .99481 | 1365.54 | 1.21889 | .1311 |
| 2450. | .4000 | 135.3830 | .99654 | 1366.53 | 1.23974 | .1298 |
| 2450. | .2000 | 271.2360 | .99827 | 1367.52 | 1.27520 | .1285 |
| 2475. | 32.3238 | 1.2967 | .76473 | 1238.24 | .98517 | .3206 |
| 2475. | 32.0000 | 1.3151 | .76780 | 1239.80 | .98609 | .3155 |
| 2475. | 31.0000 | 1.3734 | .77682 | 1244.42 | .98891 | .3017 |
| 2475. | 30.0000 | 1.4346 | .78523 | 1248.79 | .99171 | .2903 |
| 2475. | 29.0000 | 1.4990 | .79317 | 1252.98 | .99449 | .2807 |
| 2475. | 28.0000 | 1.5674 | .80073 | 1257.02 | .99729 | .2725 |
| 2475. | 27.0000 | 1.6402 | .80799 | 1260.95 | 1.00011 | .2652 |
| 2475. | 26.0000 | 1.7181 | .81502 | 1264.80 | 1.00298 | .2588 |
| 2475. | 25.0000 | 1.8018 | .82185 | 1268.58 | 1.00590 | .2530 |
| 2475. | 24.0000 | 1.8921 | .82854 | 1272.33 | 1.00889 | .2476 |
| 2475. | 23.0000 | 1.9901 | .83513 | 1276.04 | 1.01195 | .2426 |
| 2475. | 22.0000 | 2.0968 | .84165 | 1279.75 | 1.01511 | .2379 |
| 2475. | 21.0000 | 2.2135 | .84812 | 1283.45 | 1.01837 | .2334 |
| 2475. | 20.0000 | 2.3419 | .85458 | 1287.17 | 1.02174 | .2290 |
| 2475. | 19.0000 | 2.4838 | .86104 | 1290.91 | 1.02525 | .2247 |
| 2475. | 18.0000 | 2.6415 | .86753 | 1294.68 | 1.02891 | .2205 |
| 2475. | 17.0000 | 2.8180 | .87405 | 1298.48 | 1.03274 | .2162 |
| 2475. | 16.0000 | 3.0166 | .88064 | 1302.32 | 1.03675 | .2119 |
| 2475. | 15.0000 | 3.2420 | .88729 | 1306.22 | 1.04097 | .2075 |
| 2475. | 14.0000 | 3.5000 | .89402 | 1310.16 | 1.04544 | .2031 |
| 2475. | 13.0000 | 3.7980 | .90084 | 1314.16 | 1.05018 | .1985 |
| 2475. | 12.0000 | 4.1461 | .90777 | 1318.22 | 1.05524 | .1938 |
| 2475. | 11.0000 | 4.5580 | .91480 | 1322.33 | 1.06067 | .1890 |
| 2475. | 10.0000 | 5.0530 | .92194 | 1326.51 | 1.06654 | .1841 |
| 2475. | 9.0000 | 5.6586 | .92920 | 1330.75 | 1.07294 | .1790 |
| 2475. | 8.0000 | 6.4165 | .93658 | 1335.06 | 1.07999 | .1738 |
| 2475. | 7.0000 | 7.3919 | .94408 | 1339.43 | 1.08785 | .1684 |
| 2475. | 6.0000 | 8.6935 | .95170 | 1343.86 | 1.09679 | .1629 |
| 2475. | 5.0000 | 10.5172 | .95945 | 1348.35 | 1.10717 | .1573 |
| 2475. | 4.0000 | 13.2543 | .96732 | 1352.90 | 1.11964 | .1515 |
| 2475. | 3.0000 | 17.8184 | .97531 | 1357.52 | 1.13541 | .1456 |
| 2475. | 2.0000 | 26.9499 | .98342 | 1362.19 | 1.15718 | .1396 |
| 2475. | 1.0000 | 54.3510 | .99165 | 1366.91 | 1.19358 | .1334 |
| 2475. | .8000 | 68.0524 | .99331 | 1367.87 | 1.20515 | .1322 |
| 2475. | .6000 | 90.8886 | .99498 | 1368.82 | 1.22001 | .1310 |
| 2475. | .4000 | 136.5616 | .99665 | 1369.78 | 1.24085 | .1297 |
| 2475. | .2000 | 273.5818 | .99832 | 1370.73 | 1.27630 | .1285 |
| 2500. | 33.9590 | 1.2337 | .75791 | 1238.27 | .98327 | .3309 |
| 2500. | 33.0000 | 1.2850 | .76719 | 1242.94 | .98596 | .3145 |
| 2500. | 32.0000 | 1.3406 | .77612 | 1247.49 | .98870 | .3006 |
| 2500. | 31.0000 | 1.3987 | .78444 | 1251.80 | .99142 | .2893 |
| 2500. | 30.0000 | 1.4598 | .79229 | 1255.92 | .99412 | .2797 |
| 2500. | 29.0000 | 1.5244 | .79975 | 1259.88 | .99683 | .2714 |
| 2500. | 28.0000 | 1.5929 | .80690 | 1263.73 | .99957 | .2642 |
| 2500. | 27.0000 | 1.6661 | .81381 | 1267.49 | 1.00233 | .2578 |
| 2500. | 26.0000 | 1.7444 | .82052 | 1271.18 | 1.00515 | .2520 |
| 2500. | 25.0000 | 1.8287 | .82708 | 1274.83 | 1.00802 | .2467 |
| 2500. | 24.0000 | 1.9197 | .83353 | 1278.44 | 1.01096 | .2418 |
| 2500. | 23.0000 | 2.0185 | .83989 | 1282.04 | 1.01399 | .2372 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 2500. | 22.0000 | 2.1261 | .84620 | 1285.63 | 1.01710 | .2328 |
| 2500. | 21.0000 | 2.2438 | .85247 | 1289.23 | 1.02033 | .2285 |
| 2500. | 20.0000 | 2.3734 | .85874 | 1292.84 | 1.02367 | .2244 |
| 2500. | 19.0000 | 2.5165 | .86502 | 1296.47 | 1.02714 | .2203 |
| 2500. | 18.0000 | 2.6757 | .87133 | 1300.13 | 1.03076 | .2163 |
| 2500. | 17.0000 | 2.8538 | .87768 | 1303.83 | 1.03455 | .2122 |
| 2500. | 16.0000 | 3.0543 | .88409 | 1307.57 | 1.03853 | .2081 |
| 2500. | 15.0000 | 3.2818 | .89057 | 1311.36 | 1.04272 | .2039 |
| 2500. | 14.0000 | 3.5421 | .89713 | 1315.19 | 1.04714 | .1996 |
| 2500. | 13.0000 | 3.8428 | .90377 | 1319.08 | 1.05185 | .1953 |
| 2500. | 12.0000 | 4.1940 | .91051 | 1323.02 | 1.05687 | .1908 |
| 2500. | 11.0000 | 4.6097 | .91734 | 1327.02 | 1.06226 | .1862 |
| 2500. | 10.0000 | 5.1090 | .92429 | 1331.08 | 1.06809 | .1815 |
| 2500. | 9.0000 | 5.7200 | .93134 | 1335.20 | 1.07445 | .1766 |
| 2500. | 8.0000 | 6.4846 | .93851 | 1339.37 | 1.08145 | .1716 |
| 2500. | 7.0000 | 7.4684 | .94580 | 1343.61 | 1.08927 | .1665 |
| 2500. | 6.0000 | 8.7813 | .95319 | 1347.91 | 1.09816 | .1613 |
| 2500. | 5.0000 | 10.6207 | .96071 | 1352.26 | 1.10850 | .1559 |
| 2500. | 4.0000 | 13.3813 | .96834 | 1356.68 | 1.12092 | .1504 |
| 2500. | 3.0000 | 17.9845 | .97609 | 1361.14 | 1.13664 | .1447 |
| 2500. | 2.0000 | 27.1940 | .98395 | 1365.67 | 1.15836 | .1390 |
| 2500. | 1.0000 | 54.8286 | .99192 | 1370.25 | 1.19471 | .1332 |
| 2500. | .8000 | 68.6468 | .99353 | 1371.17 | 1.20627 | .1320 |
| 2500. | .6000 | 91.6776 | .99514 | 1372.09 | 1.22112 | .1308 |
| 2500. | .4000 | 137.7397 | .99676 | 1373.02 | 1.24194 | .1296 |
| 2500. | .2000 | 275.9272 | .99838 | 1373.94 | 1.27739 | .1284 |
| 2525. | 35.6462 | 1.1734 | .75035 | 1237.99 | .98132 | .3442 |
| 2525. | 35.0000 | 1.2057 | .75707 | 1241.31 | .98313 | .3306 |
| 2525. | 34.0000 | 1.2569 | .76667 | 1246.12 | .98587 | .3134 |
| 2525. | 33.0000 | 1.3099 | .77550 | 1250.61 | .98854 | .2996 |
| 2525. | 32.0000 | 1.3652 | .78374 | 1254.85 | .99118 | .2882 |
| 2525. | 31.0000 | 1.4232 | .79149 | 1258.89 | .99381 | .2786 |
| 2525. | 30.0000 | 1.4843 | .79885 | 1262.79 | .99643 | .2703 |
| 2525. | 29.0000 | 1.5491 | .80591 | 1266.56 | .99908 | .2631 |
| 2525. | 28.0000 | 1.6179 | .81270 | 1270.24 | 1.00176 | .2567 |
| 2525. | 27.0000 | 1.6915 | .81930 | 1273.85 | 1.00447 | .2510 |
| 2525. | 26.0000 | 1.7703 | .82574 | 1277.40 | 1.00724 | .2458 |
| 2525. | 25.0000 | 1.8552 | .83205 | 1280.92 | 1.01007 | .2409 |
| 2525. | 24.0000 | 1.9470 | .83827 | 1284.42 | 1.01297 | .2364 |
| 2525. | 23.0000 | 2.0465 | .84442 | 1287.90 | 1.01596 | .2321 |
| 2525. | 22.0000 | 2.1550 | .85054 | 1291.39 | 1.01904 | .2280 |
| 2525. | 21.0000 | 2.2738 | .85663 | 1294.88 | 1.02223 | .2240 |
| 2525. | 20.0000 | 2.4045 | .86272 | 1298.39 | 1.02554 | .2201 |
| 2525. | 19.0000 | 2.5490 | .86883 | 1301.93 | 1.02898 | .2162 |
| 2525. | 18.0000 | 2.7096 | .87497 | 1305.49 | 1.03257 | .2123 |
| 2525. | 17.0000 | 2.8893 | .88116 | 1309.09 | 1.03632 | .2084 |
| 2525. | 16.0000 | 3.0916 | .88740 | 1312.73 | 1.04026 | .2045 |
| 2525. | 15.0000 | 3.3212 | .89371 | 1316.41 | 1.04442 | .2005 |
| 2525. | 14.0000 | 3.5838 | .90010 | 1320.14 | 1.04881 | .1964 |
| 2525. | 13.0000 | 3.8872 | .90656 | 1323.92 | 1.05348 | .1922 |
| 2525. | 12.0000 | 4.2416 | .91312 | 1327.76 | 1.05846 | .1879 |
| 2525. | 11.0000 | 4.6609 | .91978 | 1331.64 | 1.06381 | .1835 |
| 2525. | 10.0000 | 5.1647 | .92653 | 1335.58 | 1.06961 | .1790 |
| 2525. | 9.0000 | 5.7810 | .93339 | 1339.58 | 1.07592 | .1743 |
| 2525. | 8.0000 | 6.5522 | .94036 | 1343.64 | 1.08289 | .1696 |
| 2525. | 7.0000 | 7.5446 | .94743 | 1347.75 | 1.09067 | .1647 |
| 2525. | 6.0000 | 8.8687 | .95462 | 1351.92 | 1.09951 | .1597 |
| 2525. | 5.0000 | 10.7238 | .96191 | 1356.14 | 1.10980 | .1545 |
| 2525. | 4.0000 | 13.5079 | .96932 | 1360.42 | 1.12218 | .1493 |
| 2525. | 3.0000 | 18.1502 | .97683 | 1364.75 | 1.13786 | .1439 |

## APPENDIX B

### THERMODYNAMIC PROPERTIES OF POTASSIUM VAPOR (cont'd)
(Monomer Gas Base)

| $t$ | $p$ | $v^g$ | $z$ | $h^g$ | $s^g$ | $c_p^g$ |
|---|---|---|---|---|---|---|
| 2525. | 2.0000 | 27.4376 | .98445 | 1369.14 | 1.15953 | .1385 |
| 2525. | 1.0000 | 55.3058 | .99217 | 1373.57 | 1.19583 | .1329 |
| 2525. | .8000 | 69.2408 | .99373 | 1374.46 | 1.20738 | .1318 |
| 2525. | .6000 | 92.4661 | .99529 | 1375.36 | 1.22222 | .1306 |
| 2525. | .4000 | 138.9173 | .99686 | 1376.25 | 1.24303 | .1295 |
| 2525. | .2000 | 278.2721 | .99843 | 1377.15 | 1.27847 | .1284 |

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