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June 21, 1980

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A LITERATURE SEARCH FOR THE NON-AQUEOUS SEPARATION
OF ZINC FROM FUEL ROD CLADDING

Robert L. Sandvig

Stephen J. Dyer

Glenn A. Lambert

Charles E. Baldwin

Chemistry R&D
PROCESS CHEMISTRY AND ENGINEERING

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U. S. DEPARTMENT OF ENERGY
CONTRACT DE-AC04-76DPO3533

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Printed in the United States of America
Available from the
National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22161

Page Range	Domestic Price*
001-025	\$5.00
026-050	6.00
051-075	7.00
076-100	8.00

*All microfiche are priced at \$3.50

Prices Subject to Change Without Notice

Printed
June 21, 1980

RFP-2979
UC-79c FUEL RECYCLE
~~Applied Technology~~ BASE
TIC-4500 (Rev. 67) TECHNOLOGY

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Prepared under Contract DE-AC04-76DPO3533
for the
Albuquerque Operations Office
U.S. Department of Energy

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SUBJECT DESCRIPTORS

Alloy Systems	Molybdenum
Bibliography	Nickel
Chromium	Process Materials
Corrosion	Pyrometallurgy
Distillation	Residues
Electrorefining	Separation Processes
Elements	Solubility
Fuel Elements	Stainless Steels
Fuel Reprocessing Plants	Vacuum
Furnaces	Vapor Pressure
Iron	Vapors
Liquid Metals	Very High Temperature
Metals	Zinc

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A LITERATURE SEARCH FOR THE NON-AQUEOUS SEPARATION OF ZINC FROM FUEL ROD CLADDING

*Robert L. Sandvig, Stephen J. Dyer, Glenn A. Lambert,
and Charles E. Baldwin*

Abstract. This report reviews the literature of processes for the nonaqueous separation of zinc from dissolved fuel assembly cladding. The processes considered were distillation, pyrochemical processing, and electrorefining. The last two techniques were only qualitatively surveyed while the first, distillation, was surveyed in detail. A survey of available literature from 1908 through 1978 on the distillation of zinc was performed. The literature search indicated that a zinc recovery rate in excess of 95% is possible; however, technical problems exist because of the high temperatures required and the corrosive nature of liquid zinc. The report includes a bibliography of the surveyed literature and a computer simulation of vapor pressures in binary systems.

INTRODUCTION

The initial step in processing spent nuclear fuels is separating uranium, plutonium, and fission product oxides from the fuel assembly cladding. Dissolution of the entire fuel rod assembly in molten zinc has been proposed as one method of removing cladding from the ceramic fuel elements. Approximately nine parts zinc per one part cladding is required to dissolve the cladding material. To minimize both the consumption of zinc and the amount of waste generated by reprocessing, it has been proposed that the zinc be recovered from the zinc-cladding mixture and be recycled to the cladding dissolution process. This report reviews the literature of processes for separating zinc from dissolved cladding.

Several criteria were considered. They can be outlined as follows:

1. Automated controls
2. Remote operations

- Avoid solids
 - Handling problems
 - Transport problems
 - Minimize operational requirements
- 3. Remote maintenance
 - Materials of construction
 - Minimize maintenance
- 4. Minimize residue
 - Avoid aqueous solutions
 - Increase of residue
 - Increase process flow requirement
 - Maximize zinc recovery

Application of these criteria to the problem resulted in three options:

1. Physical — Distillation
2. Pyrochemical — Pyroredox Process
3. Electrochemical — Electrorefining

Because of anticipated problems with Options 2 and 3—problems such as introduction of a suitable electrolyte and control of the consumable electrode—the literature search was concentrated on the distillation option. Thus, only qualitative research was done on Option 3, which was used primarily for a comparison of the relative merits of distillation. Option 2 was not researched because of the complex processing required to recycle the large amounts of waste material generated.

The basis for distillation is the difference of vapor pressures between zinc and the other components. At 800 °C, the vapor pressure of zinc is over 700 billion times as great as that of iron. Because of this phenomenon, the separation operation more closely resembles a drying process than a distillation.

Systematic research of the available literature was conducted in the following manner:

```

TERMINAL MAP
SESSION 0001, FILE E08 01-19-79
*****
SET HISTORY
SET  DESCRIPTOR  CITS
1    IT=DISTILLATION 1929
2    IT=SEPARATION PROCESSES 2384
3    IT=FRACTIONATION 613
4    IT=DISTILLATION EQUIPMENT 243
5    IT=CHLORIDE VOLATILITY PROCESS 5
6    IT=EVAPORATION 1619
7    IT=EVAPORATORS 319
8    IT=REPROCESSING 1039
9    IT=REFINING 1182
10   IT=WASTE PROCESSING 1790
11   IT=VAPOR CONDENSERS 105
12   IT=DEVOLATILIZATION 15
13   IT=DEMETALLIZATION 55
14   IT=METAL TRANSFER PROCESS 1
15   IT=MULTI-ELEMENT SEPARATION 49
16   IT=REMOVAL 6489
17   IT=VAPOR SEPARATORS 55
18   IT=ZINC 2124
19   IT=MAGNESIUM 899
20   IT=MANGANESE 1015
21   IT=IRON 3650
22   IT=NICKEL 2789
23   IT=MOLYBDENUM 1880
24   IT=CALCIUM 1120
25   IT=POTASSIUM 1419
26   IT=ZIRCONIUM 846
27   IT=NIObIUM 2363
28   IT=TUNGSTEN 1502
29   IT=CHROMIUM 1177
30   IT=SODIUM 2684
31   IT=COPPER 3672
32   IT=TIN 1727
33   IT=PLUTONIUM 1401
34   IT=URANIUM 3162
35   IT=AMERICIUM 244
36   1-17/+ 16246
37   18-35/+ 22983
38   36*37 1287
39   IT=ZINC CHLORIDES 186
40   IT=VOLATILITY 371
41   IT=PYROMETALLURGY 22
42   IT=PHASE TRANSFORMATIONS 2355
43   IT=VAPORIZATION HEAT 167
44   40-43/+ 2907
45   44*37 237

```

FIGURE 1. Set History for Computerized Reference Listing of Works Published From 1975 to 1978

1. *Chemical Abstracts* from 1908 to 1961 were researched, and several reports on zinc distillation processes were obtained.
2. *Zinc Abstracts* from 1962 to 1978 were researched, and several important references were obtained, including an article on the thermodynamics of iron-zinc solutions in the 700 to 900 °C temperature range.
3. A computerized listing of reference works published between 1975 and 1978 was obtained and reviewed. A copy of the set history for this run is shown in Figure 1. This listing yielded one extensive report on the use of computers for nuclear plant controls.
4. A computerized listing of reference works published between 1967 and 1975 was

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TERMINAL MAP
SESSION 0004, FILE NSA 02-23-79
*****
SET HISTORY
SET  DESCRIPTOR  CITS
1    IT=DISTILLATION 699
2    IT=SEPARATION PROCESSES 7809
3    IT=FRACTIONATION 57
4    IT=DISTILLATION EQUIPMENT 3
5    IT=CHLORIDE VOLATILITY PROCESS 1661
6    IT=EVAPORATION 65
7    IT=EVAPORATORS 3131
8    IT=REPROCESSING 276
9    IT=REFINING 1101
10   IT=WASTE PROCESSING 19
11   IT=VAPOR CONDENSERS 3
12   IT=DEMETALLIZATION 86
13   IT=METAL TRANSFER PROCESS 319
14   IT=MULTI-ELEMENT SEPARATION 6
15   IT=REMOVAL 2799
16   IT=VAPOR SEPARATORS 2231
17   IT=ZINC 2367
18   IT=MAGNESIUM 6551
19   IT=MANGANESE 3944
20   IT=IRON 5224
21   IT=NICKEL 2981
22   IT=MOLYBDENUM 2761
23   IT=CALCIUM 3442
24   IT=POTASSIUM 4264
25   IT=ZIRCONIUM 5037
26   IT=NIOSIUM 2631
27   IT=TUNGSTEN 7147
28   IT=CHROMIUM 5890
29   IT=SODIUM 1999
30   IT=COPPER 4647
31   IT=TIN 9004
32   IT=PLUTONIUM 776
33   IT=URANIUM 8290
34   IT=AMERICIUM 1807
35   1+2 4456
36   3-7/+ 13274
37   8-14/+ 4401
38   35-37/+ 7622
39   17+18 8230
40   19+20 8335
41   21+22 10337
42   23-25/+ 13615
43   26-28/+ 12613
44   29-31/+ 15537
45   32-34/+ 16780
46   39-41/+ 25250
47   42+43 45279
48   44+45 4580
49   46-48/+ 65
50   38+49 609
51   IT=ZINC CHLORIDES 21
52   IT=VOLATILITY 1666
53   IT=PYROMETALLURGY 68
54   IT=PHASE TRANSFORMATIONS 2420
55   IT=VAPORIZATION HEAT 436
56   51-55/+
57   49*56

```

FIGURE 2. Set History for Computerized Reference Listing of Works Published From 1967 to 1975

obtained and reviewed, and a copy of the set history for this run is shown in Figure 2. As

with the other listing, few references were obtained, and not one was of major significance.

In accordance with the first item under Number 4 of the listed criteria ("avoid aqueous solutions"), aqueous treatment methods were not considered in this literature search. Additionally, some of the reference material was considered beyond the capabilities of the researchers. This material included (1) foreign patents such as those issued by the governments of Czechoslovakia, France, Federal Republic of Germany, the U.S.S.R., and others. These patents were not considered because they are difficult to obtain and translate. Reference works in foreign languages such as Japanese, Russian, German, and French were not considered unless deemed of particular importance and a translation could be obtained. These foreign works are listed in the Bibliography if the title or abstract of the work indicated that the work may contain items of value.

ZINC - 316 STAINLESS STEEL MIXTURE

Several materials have been used for cladding, including stainless steel (Types 304 and 316), 718 Inconel and Zircaloy-2. Stainless steel (Type 316) was selected as a representative cladding material. The components of 316 stainless steel and their solubility in liquid zinc are listed in Table 1.* From Table 1, it is clear that iron is the major component of 316 stainless steel. Additionally, when compared to zinc; chromium, iron, and nickel all have similar atomic radii, crystal structure, melting points, and vapor pressures. Therefore, for the purposes of rough qualitative analysis, chromium and nickel can be approximated by iron.¹ Hence, the zinc-iron binary system can be used as a model for the zinc-316 stainless steel system.

At 800 °C, the iron-zinc mixture is liquid for iron concentrations of 7.7 wt % or less. Larger concentrations of iron yield a two-phase system consisting of zinc - 7.7 wt % iron liquid phase and a zinc - 55 wt % iron solid solution phase. The zinc - 55 wt % iron solid solution, under normal conditions, will form small grains, which are suspended in the liquid phase. A solution of zinc - 10 wt % iron at 800 °C is fluid. At 783 °C, the solution solidifies if the iron concentration is greater than 7.4 wt %. Since the decladding operation is to be performed at 800 °C,

*Superscript numbers refer to corresponding numbered publications in the bibliography.

TABLE 1. Components of 316 Stainless Steel and Their Solubilities in Liquid Zinc

Component	wt %	Solubility in Zinc at 800 °C
Chromium	17	2.0% (est.)
Iron	68.5	8.2%
Molybdenum	2.5	0.022%
Nickel	12	11.3%

a zinc solvent-to-cladding weight ratio of 9:1 would yield a fluid easily transferred from the process crucible through a transfer line heated to 800 °C. A weight ratio of 13.5:1 would ensure that the system was fluid even at a temperature as low as 785 °C. Increasing the zinc solvent-to-cladding ratio would increase the throughput process requirements for the zinc cladding separation step; however, too little zinc will cause a stoppage or restriction in the transfer line. A zinc - 55 wt % iron deposit could be cleared by flushing with molten zinc or heating the tube to the melting point of the deposit (i.e. 1200 °C for zinc - 55 wt % iron).

Separation of zinc from iron can best be accomplished in the 783 to 800 °C temperature range. Figure 3 is a phase diagram for the zinc-iron binary system.¹¹ By following the 800 °C isotherm from pure zinc to pure iron, three regions are encountered. At high zinc concentrations of 92.3 wt % and greater, the entire mixture is liquid, the iron being dissolved in the zinc. As the zinc concentration decreases below 92.3 wt %, a two-phase region is entered. The two phases are a liquid solution, which is approximately 92.3 wt % zinc, and a solid solution, alpha iron, which is approximately 55 wt % iron. At 45 wt % zinc, the liquid phase disappears and only the alpha iron is left. Within the alpha iron region is a smaller region labeled gamma iron. The major difference between these two types of iron is their crystal structure, the alpha is body centered cubic and the gamma is face centered cubic.^{1,11} Because of its denser configuration, zinc diffuses from gamma iron much slower than from alpha iron. At 800 °C, the vapor pressure of zinc is 233 mm mercury; that of iron is 0.316×10^{-9} mm mercury.² Therefore, the relative volatility of zinc is 7.37×10^{11} , and zinc can be easily separated from the liquid and recovered.

Region	Crystal Structure
α Fe	Body-centered cubic
γ Fe	Face-centered cubic

FIGURE 3. Zinc-Iron Phase Diagram¹¹

However, as the zinc is removed, the iron residue is deposited and when the liquid phase disappears, the zinc/iron separation becomes a diffusion operation, which is relatively slow. At 1000 °C, diffusion of zinc from alpha iron is over 200 times as fast as from gamma iron.⁵ Since gamma iron is formed at temperatures above 801 °C, the separation process temperature should be held below 800 °C.

The actual dissolution of stainless steel in zinc does differ from the model just described. Because of the low solubilities of the stainless steel components, large quantities of zinc are required. The dissolution ratio of stainless steel in zinc has been reported to be as high as 26 wt %; however, at this ratio the solution is a pastelike slurry. At a lower loading, i.e., zinc - 20 wt % stainless steel, the solution is a pourable fluid. Thus, stainless steel can be loaded into molten zinc well above the solubility of the steel. This is possible because the iron grains are approximately the same density as the zinc and are suspended in the molten metal.² The mechanisms of dissolution are leaching of nickel from the steel followed by freeing of iron-chromium grains that are carried into solution by the zinc.^{2,18} Both 316 stainless steel and 718 Inconel contain small percentages of molybdenum that is relatively insoluble and will remain in the crucible after the zinc-cladding mixture has been transferred. This molybdenum should be removed with the other Group IV fission products.¹²

The rate at which stainless steel dissolves in the molten zinc is a function of the nickel concentration in the solution. For 304 stainless steel, the rate of dissolution varies from 0.005 mm/min at 13 wt % nickel to 0.066 mm/min with no nickel in solution. Also the presence of magnesium inhibits the rate of zinc attack (dissolution), but no quantitative information was available.^{2,18}

The three components that appear to be of greatest importance are zinc, the solvent to be recovered; iron, the major diluent; and nickel, the component controlling the dissolution rate. No phase diagram for this ternary system has been located. Copies of iron-nickel, and nickel-zinc binary phase diagrams are in Appendix B, and Olson and Toop describe a method of calculating ternary thermodynamic properties from binary system data.^{1,20}

ZINC RECOVERY – VAPOR PHASE

At zinc concentrations greater than 46 wt % and temperatures above 783 °C, the separation of zinc from iron or stainless steel more closely resembles a drying operation than a distillation. At lower zinc concentrations, the process is best described as diffusion of zinc from iron. This resemblance is due to the high relative volatility of zinc.

Because of its low melting point and high vapor pressure, zinc is relatively easy to refine by vaporizing the metal and then condensing the vapor. Metallic zinc has been produced from its ores by this process for decades. Recent work has shown that a melt consisting of 1.6-kg 304 stainless steel and 27.5-kg zinc (zinc - 5.498 wt % stainless steel) can be separated at 850 °C and 10 torr. In this particular case, 98 wt % of the zinc had been evaporated.²⁹

Several reports have been issued on distillation of zinc from aluminum.²⁵ It should be noted that aluminum has a much higher vapor pressure than any stainless steel component and thus its separation would require more exacting conditions. The experimental work for these reports were run in an induction heated furnace at extremely low pressures and comparatively moderate temperatures. The zinc vapors were condensed to a solid phase on a simple plate condenser similar to the one proposed for this zinc-cladding separation process. Assuming that the zinc-cladding mixture is fed into the separation process as a fluid of 10 wt % cladding at a temperature of approximately 790 °C, the temperature should be maintained above 783 °C to prevent the formation of a solid, and below 801 °C to prevent the formation of gamma iron. Under these conditions, the zinc, which is over 700 billion times as volatile as the iron, will vaporize and leave an iron-rich residue. When the iron content is approximately 54 to 55 wt %, the liquid should be totally evaporated, and gamma iron with a body centered cubic crystal structure should remain. At this point, the separation becomes a diffusion process. The reported diffusivity of zinc in alpha iron is over 200 times as great as the diffusivity of zinc in gamma iron. These reported diffusivities were calculated from the results of experiments carried out at temperatures in excess of 900 °C and

at pressures less than 10 mm of mercury. Studies were undertaken on varied zinc concentrations from 1 to 11 at. % with the diffusion coefficient decreasing with decreasing zinc concentrations.⁵ Residue of the zinc - 304 stainless steel separation mentioned earlier was described as a "hard sintered mass," but nothing specific was mentioned concerning its porosity.²⁹ If this residue was porous, then the increased surface area would significantly increase the mass of zinc that could diffuse out of the residue. This also would have the effect of reducing the amount of iron that the zinc would have to diffuse through.

The rate of zinc evaporation from the liquid phase, using distillation techniques, has been developed in several references. Vivian specifies a relative volatility range of 50 to 10,000 and a mole fraction of the volatile material of 0.5 or less.²⁸ St. Clair and Spendlove's work is concerned with the evaporation rate of zinc from a pool of pure zinc; however, their work appears to be the most relevant for simplified rate calculations.²⁶ According to St. Clair and Spendlove,

$$W_o = \frac{28.30}{T^{1/2}} P_o \quad (1)$$

where

W_o = maximum rate of evaporation of zinc in grams/cm² min

T = temperature in K

P_o = vapor pressure of zinc (in mm of mercury)

and

$$W = \frac{28.30}{T^{1/2}} (P_o - P) \quad (2)$$

where

W = actual rate of evaporation of zinc in grams/cm² min

P = partial pressure of zinc (in mm of mercury)

Since the relative volatility of zinc is much greater than any other component of the system, the mole

TABLE 2. Diffusivity Coefficients for Zinc in Iron

Temperature (°C)	Diffusivity in γ -Fe (cm ² /sec)		Diffusivity in α -Fe (cm ² /sec)
	Zn = 1 at. %	Zn = 2 at. %	Zn = 11 at. %
950			5.7×10^{-10}
1000	5.2×10^{-12}	6.00×10^{-12}	
1009			1.4×10^{-9}
1016	6.10×10^{-12}	7.90×10^{-12}	
1049	1.14×10^{-11}	1.41×10^{-11}	
1060	1.44×10^{-11}	1.75×10^{-11}	3.82×10^{-9}
1095			5.81×10^{-9}
1151			1.37×10^{-8}
1152	6.87×10^{-11}	8.39×10^{-11}	

fraction of zinc in the vapor phase will be essentially 1.0; P will be equal to the total pressure. Therefore, if the total pressure is lower than the vapor pressure of zinc, the zinc will readily evaporate. Although Equation 2 appears to indicate that the rate of evaporation would increase for decreasing temperature, it must be remembered that P is also a function of temperature. It also should be noted that the pressure difference has a greater effect on the evaporation rate than does temperature. With pressures in the range of 10^{-1} to 10^{-2} mm of mercury, evaporation rates of 10 g/(cm² min) at 600 °C were reported.²⁶

The rate-of-diffusion of zinc from solid iron varies with temperature and zinc concentration. Reported values are shown in Table 2 and in Figure 4.⁵

All three sets of data yield straight lines when the logarithm of the diffusivity is plotted versus the temperature, as shown in Figure 4. When extrapolated to a temperature of 795 °C, the value of the diffusivity coefficient of zinc in gamma iron is 2.1×10^{-11} cm²/sec for a zinc concentration of 11 at. %. As can be seen from the gamma-iron diffusivities, the coefficient decreases with decreasing zinc concentration, but with the limited data available, the relationship cannot be determined. However, since the zinc begins diffusing when its concentration is 45-46 wt %, using the diffusion

FIGURE 4. Diffusivities of Zinc in Iron

coefficient for 11 at. % (11 at. % = 13 wt %), the calculated recovery rate should be somewhat lower than the actual rate.

From Fick's law of diffusion¹⁶

$$I_{Zn} = \frac{N_{Zn}}{A} = -D_{Zn} \frac{d C_{Zn}}{d b} \quad (3)$$

where I_{Zn} = the mass flux of zinc in g mol/(cm² sec)

N_{Zn} = the rate of mass transfer of zinc in g mol/sec

A = the area of mass transfer of zinc in cm²

D_{Zn} = the diffusivity coefficient of zinc

C_{Zn} = the concentration of zinc in g mol/cm³

b = the distance from phase boundary in cm

As can be seen from Equation 3, the driving force for the diffusion is the concentration gradient. Assuming the zinc vapor behaves as an ideal gas, the zinc concentration in the vapor over the zinc-iron mixture would be approximately 1.5×10^{-7} g mol/cm³ at a total pressure of 10 mm of mercury. The concentration of zinc in the iron would vary from approximately 4.9×10^{-2} g mol/cm³ to 2.18×10^{-3} g mol/cm³, depending on the fraction of zinc present. No specific listing of the diffusion distance was found; however, the iron atoms approach no closer than about 2.5 Å (Å = 10^{-8} cm).¹ Substituting this information into Equation 3 to obtain maximum and minimum rates yields the following:

$$\begin{aligned} I_{MAX} &= -D_{Zn} \frac{d C_{Zn}}{d b} \\ &= 2.1 \times 10^{-11} \frac{4.9 \times 10^{-2}}{10 \times 10^{-8}} \\ &= 1.029 \times 10^{-5} \frac{\text{g mol Zn}}{\text{cm}^2 \text{ sec}} \\ &= 6.72 \times 10^{-4} \frac{\text{g Zn}}{\text{cm}^2 \text{ sec}} \\ &= 2.42 \frac{\text{g Zn}}{\text{cm}^2 \text{ hr}} \end{aligned}$$

$$\begin{aligned} I_{MIN} &= D_{Zn} \frac{d C_{Zn}}{d b} \\ &= 2.1 \times 10^{-11} \frac{2.18 \times 10^{-3}}{20 \times 10^{-8}} \\ &= 2.289 \times 10^{-7} \frac{\text{g mol Zn}}{\text{cm}^2 \text{ sec}} \\ &= 1.497 \times 10^{-5} \frac{\text{g Zn}}{\text{cm}^2 \text{ sec}} \\ &= 5.3876 \times 10^{-2} \frac{\text{g Zn}}{\text{cm}^2 \text{ hr}} \end{aligned}$$

Using the methods just described, 100% of the zinc is recoverable. If one metric ton of feed (90 wt % zinc, 10 wt % cladding) were separated in a circular vessel one meter in diameter at 795 °C and 10 mm of mercury, all the zinc would be vaporized in less than 7 hr. Of the 7 hr required, 6.8 hr are required to diffuse 45 kg of zinc from the gamma iron. Vaporization of the 855 kg of zinc theoretically required 36 sec, which is obviously incorrect. Two major reasons for this discrepancy are (1) The total pressure of only 10 mm of mercury cannot be maintained because the evaporating zinc will fill the vapor space and thus reduce the vacuum. This will slow the rate at which the zinc evaporates. (2) Because of the latent heat of vaporization, there exists a significant temperature gradient from the bulk of the liquid to a comparatively cool evaporation surface. Spendlove reported a temperature difference of 35 °C, but stated that it may reach 100 °C or more at high rates of evaporation.²⁶ Using more realistic parameters such as an evaporation surface temperature of 600 °C and a pressure differential of 0.5 mm of mercury, the theoretical time required for this separation is 3 hr.

Because of its high relative volatility, the recovered zinc will be essentially pure. The only foreseeable contamination would come from an extremely small amount of iron vapor condensing in the zinc. Therefore the amount of makeup zinc required will have to be determined by experiment.

Figure 5 depicts the possible configuration of a vapor-phase zinc-cladding separator. The zinc-cladding mixture would be fed into the top of the

FIGURE 5. Conceptual Equipment Configuration for Zinc-Cladding Vapor-Phase Separation Unit

steel crucible from the decladding process. The crucible would then be lowered into the induction heater coil and then capped with the radiative condenser. Next, the evacuated housing would be lowered into place and evacuated. As the induction coil heats the zinc cladding mixture, the zinc would be vaporized and the zinc vapors would condense and collect in the condenser. The liquid zinc could then be tapped off and cast into an easily transported shape. When the separation is complete and the vacuum releases the steel crucible, the separation residue could be removed and used as a waste storage container. Specific utilities requirements will vary with the particular apparatus and the temperature of the initial feed. Theoretical calculations show that approximately 0.5 kilowatt hours will be required for each kilogram of zinc vaporized. Induction furnaces of the required size are available commercially. The problem with construction materials is obtaining materials that will resist zinc attack. Only tungsten and tantalum have been proven resistive to zinc attack.⁸

ELECTROREFINING

To recover zinc from the zinc - stainless steel mixture by electrolysis, the zinc must be oxidized to a salt such as zinc chloride. This can be accomplished by adding the chloride salt of a metal that has smaller electropotential than zinc (e.g., FeCl_2), which will result in the following reaction:

The zinc chloride can be separated from the metallic iron and then can be decomposed by electrolysis, according to the following half cell reaction:¹⁰⁵

Reaction		E° (volts)
$\text{Zn}^{++} + 2e^- = \text{Zn(s)}$		-0.76
$2\text{Cl}^- = \text{Cl}_2(\text{g}) + 2e^-$		-1.36
NET	$\text{Zn}^{++} + 2\text{Cl}^- = \text{Zn(s)} + \text{Cl}_2(\text{g})$	-2.12

The amount of zinc deposited at the cathode of the cell is determined by the energy input to the cell. To deposit one gram-mole of zinc requires the transfer of two gram-moles of electrons or two Faradays, which is 193,000 coulombs. The product of this value and the voltage required to drive the reaction (2.12 volts) results in the amount of energy needed to recover one gram-mole of zinc, which is 409,160 Joules. This value equals 1.7387 kilowatt hours required per kilogram of zinc deposited, or 97.75 kilocalories per mole of zinc. This is the minimum amount of energy required based on theoretical calculations. The rate of zinc recovery will depend on the amount of electrical current flowing through the cell. Production of one kilogram of zinc per hour requires a current flow of 820 amperes. The current flow will depend on the electrical resistance of the cell and the voltage applied to the cell. A voltage substantially greater than the 2.12-volt minimum may be required to produce the zinc at a sufficient rate. This increased voltage requirement will cause a proportional increase in the energy requirements previously calculated.

This method of separating zinc from stainless steel involves several process steps and the introduction of more materials to process.¹⁹ The conversion of metallic zinc to a salt requires the addition of FeCl_2 , which probably would have to be produced by recombining the iron with chlorine produced at the anode of the cell. Since the electropotential of iron is less than that of zinc, the amount of FeCl_2 added cannot be in excess of the amount required to oxidize the zinc. Any excess FeCl_2 will remain with ZnCl_2 in the electrolyte, causing iron to be deposited with the zinc at the cathode. Any magnesium present in the melt will be oxidized to a salt preferentially to the zinc because of the magnesium's larger electropotential. However, this magnesium will remain in the molten electrolyte if the voltage across the cell is less than 3.13 volts.

The equipment for this process is similar to that for recovering aluminum from aluminum oxide, which is a well-known and well-tested process. The operating temperature of the zinc electrolysis is much less than that of the aluminum process, since ZnCl_2 melts at 283 °C and Al_2O_3 melts at 2045 °C. Below the melting point of ZnCl_2 , zinc

is deposited as a solid at the cathode; if, however, the operating temperature is above the melting point of zinc, 420 °C, the zinc will collect as a liquid at the bottom of the cell.

The energy required to electrolytically separate one gram-mole of zinc is greater than the heat required to vaporize one gram-mole of zinc. The heat of vaporization of zinc at 800 °C is approximately 27.7 kcal/g-mol, whereas the energy for electrolysis was calculated to be 97.75 kcal/g-mol of zinc.

The electrorefining option was not investigated in as great a detail as distillative recovery of zinc, but from a basic review of the process and some fundamental calculations, a general comparison of the two processes can be made. From the standpoint of theoretical energy required for both processes, distillation requires less energy input, although inefficiency of the induction furnace may cause a significant increase in the energy requirements for distillation. Since electrolytic cells are generally quite efficient, the theoretical value for the energy required should be quite close to the actual value. The electrolytic process can operate at a much lower temperature than the distillation process and can be carried out under atmospheric pressure. Because of the number of individual processes involved in electrorefining (e.g. oxidation of zinc and processing of chlorine), this method of recovering zinc is not as practical as distillation.

SYSTEM CONTROL AND SAFETY

Several articles were found concerning the specific equipment design used in various nuclear facilities. Each design was tailored to meet specific process requirements, however, and no general information concerning design considerations was obtained that was useful for this report.

One study on control systems was extensive and informative.²² This study reviews (1) the process being controlled, (2) measurable variables, and (3) methods used to measure the control variables. Several diagrams depict the process configuration and controllers. The study reviews available operational modes, the computer hardware system, and

describes the system test runs. The equipment was reported to show a high degree of reliability and the only problems encountered were in the electronics. Examples of the problems were discriminators and high voltage supplies. Good control was exhibited on process streams. The report concludes that in-line instrumentation, continuous process monitoring, and computerized analysis and control are thoroughly suitable for nuclear plants.

Primary considerations for control system design of the zinc-cladding separation process are (1) isolation of radioactive materials, (2) quality assurance for recycled zinc, and (3) temperature monitoring and control. Isolation of the recycle materials can be accomplished with standard shielding techniques and electronic transmission of process variables to monitors outside the isolated cell. The purity of recycled zinc could be checked easily by measuring electrical resistivity at a known temperature. Temperature measuring and control are extremely critical because of the high temperatures involved. Precise temperature control will also be required because the expected process is a vapor-liquid separation.

Required process control equipment and data samplers are available commercially and have predictable reliability. The problem is that the controllers and data samplers in contact with the liquid zinc must be fabricated from materials resistant to zinc attack. Only tungsten and tantalum have been reported resistant to zinc attack at elevated temperatures.⁸ Remote maintenance equipment will have to be designed for its specific application.

Because of the required cool-down period for fuel-rod assemblies, radiation levels in zinc-cladding separation are not expected to be excessive. Because the process is essentially a batch operation, a shut-down would merely stop the process before completing the cycle. No large pressures would have to be relieved, but to open the system, the vacuum in the evaporation chamber would have to be relieved. Since this is a vacuum, the relief would not produce an effluent. As noted earlier, zinc is extremely corrosive, and a spill caused by container fracture could cause extensive damage to the system.

Because the suggested equipment configuration (see Figure 5) locates the steel crucible directly below the condenser, an overflow is possible only during the initial charging of the feed to the separator. Again, costly damage could result from an overflow or excessive splashing.

SUGGESTED FUTURE WORK

Further investigation and experimentation should be conducted in several areas relative to the distillation process. Because of the lack of experimental data on the multicomponent stainless steel - zinc mixture, a basic assumption made at the outset of this study was that the system could be closely approximated by an iron-zinc system. The possibility of interactions of iron and zinc with nickel and chromium, which comprise a significant percentage of the stainless steel, indicates the need for phase data on these multicomponent systems. These data were not found in this literature search. The systems in need of further experimental research are zinc - stainless steel 316, zinc - stainless steel 304, zinc - 718 Inconel, and zinc - Zircaloy, since these alloys are used as fuel-rod cladding materials. A ternary phase diagram of the iron-nickel-zinc system would be extremely helpful since zinc preferentially dissolves the nickel in stainless steel.

Another area that requires further experimental investigation is the effect of nickel on the dissolution of stainless steel in zinc. Since zinc appears to have an affinity for nickel, nickel may also have an effect on the solid solutions formed as zinc is removed by evaporation. The role nickel plays in the mechanism of dissolution should also be studied. Magnesium also has an effect on the rate of dissolution of metals in zinc, according to DeKany.⁸ Since magnesium may be brought into the decladding distillation process, this subject area may warrant further investigation. There may be an appreciable carryover of magnesium. This would cause some amount of magnesium to be in the zinc solvent for decladding and would therefore retard the rate at which cladding is dissolved. Because of the corrosive effect of liquid zinc, experimental work should be performed to determine the effects of liquid zinc on possible construction materials such as tungsten or

tantalum. Since zinc vapor is less corrosive than liquid zinc, any materials found to be resistive to liquid zinc should be suitable as a construction material.³ The type of construction material determined to be necessary to sufficiently resist corrosion may be an important consideration in the design and fabrication of distillation process equipment.

This study did not consider in detail the equipment configurations necessary to facilitate remote operation of the process or remote maintenance of equipment. Further investigation in this area is necessary in that these considerations may cause significant modifications to any basic design of a distillation system. Since remote operation and maintenance are both basic requirements placed on the system, further work in this area appears warranted.

Results of this study, both data obtained and reference material cited, should be sufficient as a basis for developing a simulation of the process. This simulation could then be used to determine optimum parameters for operation of the process. This could include equipment design, operating temperature of the process, product composition, percent recovery of zinc (consistent with time limitations for processing), and several other important process variables. This study could be conducted in two portions since the separation consists of two different types of operations. The first of these would be an actual distillation of liquid zinc from the components of stainless steel. This would include the liquid phase and the solid plus liquid phases of the system. The other operation would be the removal of zinc from the solid solution phase, which appears to resemble a diffusion-controlled drying operation. These two operations could be considered from two different approaches: first, a simplified version of the actual system, which assumes that the system can be closely approximated by the binary system of zinc and iron; secondly, simulation of a system of this type could then be refined to include the effects of the other component of the actual system. This final system could then be utilized to determine the necessary process parameters.

An important consideration that needs further investigation is the economics of the process. Theoretical energy requirements were calculated during the course of this study; however, this does not include any consideration for energy losses and inefficiencies in the process and equipment that could significantly increase energy requirements. The cost of fabricating equipment from materials resistive to zinc corrosion could be significant and should be examined once a determination has been made as to construction materials. This cost will have a bearing on the selection of construction materials if there is a choice in the matter.

SUMMARY

The literature search indicates that recycling zinc in the decladding step is physically possible and of interest economically when considering the cost of permanent storage. Of the nonaqueous methods reviewed, recovery of zinc by vaporization appears to be the best method. The vaporization method is the least complex and uses the least amount of energy. Problems of the vaporization method center around two major concerns:

1. Liquid zinc is extremely corrosive. Fabrication of plant-scale apparatus with materials resistive to zinc corrosion attack will be expensive.
2. The process temperatures are high, 800 °C, and must be rigidly controlled to maximize efficiency.

This literature search has yielded sufficient data to begin assembly of a computer simulation of the zinc-cladding separation process. Concurrent with the computer simulation, experimental work on the zinc-cladding system to determine and confirm rates of dissolution, evaporation, and diffusion needs to be done.

The literature search indicates that zinc recovery in excess of 95% is obtainable. Several reference sources that were deemed important were not obtained. These sources, along with information obtained from the proposed computer simulation and experimental work, should provide the necessary data to design a pilot-scale apparatus.

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APPENDIX A

VAPOR PRESSURES OF SYSTEM COMPONENTS

The variance in vapor pressures between two materials is the basis for the mass transfer processes of distillation and drying. Vapor pressures vary with temperature. Appendix C of RFP-2865 lists four data points for each of the anticipated system components.² A plot of these data points is shown in Figure A-1. Noting that the ordinate is logarithmic, one can see that at 800 °C the vapor pressure of zinc is over 700 billion times as great as that of iron.

One method of correlating vapor pressure and temperature is the Antoine equation:

$$\log P = A - \frac{B}{C + T} \quad (A-1)$$

where P is vapor pressure in mm Hg, T is temperature in K, and A, B, and C are empirical constants.

To evaluate A, B, and C, three data points are needed for each substance.

$$\log P_1 = A - \frac{B}{C + T_1}$$

$$C(\log P_1) + T_1(\log P_1) - AT_1 = AC - B$$

and

$$C(\log P_2) + T_2(\log P_2) - AT_2 = AC - B \quad (A-2)$$

Setting left hand sides equal,

$$\begin{aligned} C(\log P_1) + T_1(\log P_1) - AT_1 \\ = C(\log P_2) + T_2(\log P_2) - AT_2 \end{aligned}$$

$$\begin{aligned} C(\log P_1 - \log P_2) \\ = T_2(\log P_2) - T_1(\log P_1) + A(T_1 - T_2) \end{aligned}$$

$$C = \frac{T_2(\log P_2) - T_1(\log P_1) + A(T_1 - T_2)}{\log(P_1/P_2)} \quad (A-3)$$

also,

$$C = \frac{T_3(\log P_3) - T_2(\log P_2) + A(T_2 - T_3)}{\log(P_2/P_3)}$$

Setting right hand sides equal and expanding results in

$$\begin{aligned} A \frac{T_1 - T_2}{\log(P_1/P_2)} - \frac{T_1 - T_2}{\log(P_2/P_3)} \\ = \frac{T_3(\log P_3) - T_2(\log P_2)}{\log(P_2/P_3)} \\ - \frac{T_2(\log P_2) - T_1(\log P_1)}{\log(P_1/P_2)} \end{aligned}$$

Isolating A results in Equation A-4*

Substituting the value obtained from Equation A-4 into Equation A-3 will yield a value for C. Rearranging Equation A-1 yields

$$B = (C + T) \times (A - \log P)$$

Substituting calculated values for A and C will yield B.

Utilizing the computer program shown in Table A-1, both the upper three and lower three data points were used to evaluate the empirical constants of the Antoine equation. Different results were obtained for the two data sets used. These results are listed in Table A-2. As can be seen from the table, the differences are significant; however, the

$$*A = \frac{T_3(\log P_3) \log(P_1/P_2) - T_2(\log P_2) \log(P_1/P_3) + T_1(\log P_1) \log(P_2/P_3)}{T_1 \log(P_2/P_3) - T_2 \log(P_1/P_3) + T_3 \log(P_1/P_2)} \quad (A-4)$$

differences in the computed vapor pressures are rather small. Figure A-2 is a plot of the vapor pressures of zinc, which were calculated using the two sets of empirical constants. Also plotted are the reference data points. Good agreement is shown in the center section of the curve; the widest divergence occurs at the low temperature end of the curve. Also on the plot is a small diagram on a greatly exaggerated scale that depicts the relationship of the two curves and the expected process-operating temperature range, which is limited on the lower end by solubility and on the upper end by diffusion rates. This range is much smaller than the overall temperature and furthermore, it lies in an area of good agreement. Table A-3 lists percent deviation of the vapor pressures. These pressures were calculated

using empirical constants derived from the low-temperature data points from the calculated vapor pressures using the high temperature data points. As can be seen from the table, agreement is good except for molybdenum. Molybdenum, however, comprises only a small fraction of the system, and its vapor pressure is so low it is negligible.

Vapor pressures for various temperatures are shown for chromium (Table A-4), iron (Table A-5), magnesium (Table A-6), molybdenum (Table A-7), nickel (Table A-8), and zinc (Table A-9). The pressures shown in these tables were calculated from the Antoine equation. Each page lists (1) the metal, (2) the Antoine equation constants, (3) data points used to calculate the constants, and (4) vapor pressures for various temperatures.

TABLE A-1. Listing of the Computer Program Utilizing the Antoine Equation

```

00100 PROGRAM ANTOIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
00110 WRITE(6,3)
00120 3 FORMAT(*ENTER NUMBER OF VAPOR PRESSURE EQNS TO BE CALCULATED*)
00130 READ(5,*)N
00140 DO 25 J=1,N
00150 WRITE(6,4)
00160 READ(5,2)NAME
00170 4 FORMAT(*ENTER NAME OF METAL*)
00180 2 FORMAT(A10)
00190 WRITE(6,11)
00200 11 FORMAT(*ENTER TEMP RANGE AND INTERVAL: T1,TE,INT*)
00210 READ(5,*)K,L,M
00220 WRITE(6,6)
00230 6 FORMAT(*ENTER T1,P1,T2,P2,T3,P3*)
00240 READ(5,*)T1,P1,T2,P2,T3,P3
00250 WRITE(6,12)
00260 12 FORMAT(*ENTER TEMP UNITS AND PRESSURE UNITS: I.E. C,K,F,R %,
00270+*8 MM HG, ATM, ETC.*)
00280 READ(5,13)IT,IP
00290 13 FORMAT(A1,A6)
00300 TA=T1
00310 TB=T2
00320 TC=T3
00330 TD=0.
00340 IF(IT.EQ.1HK.OR.IT.EQ.1HR)GO TO 14
00350 IF(IT.EQ.1HC)GO TO 16
00360 IF(IT.NE.1HF)GO TO 30
00370 TD=460.
00380 GO TO 12
00390 16 TD=273.15
00400 17 TA=T1+TD
00410 TB=T2+TD
00420 TC=T3+TD
00430 14 AL1=TA*ALOG10(P2/P3)
00440 AL2=TB*ALOG10(P1/P3)
00450 AL3=TC*ALOG10(P1/P2)
00460 AN=AL1*ALOG10(P1)-AL2*ALOG10(P2)+AL3*ALOG10(P3)
00470 AD=AL1-AL2+AL3
00480 A=AN/AD
00490 C4=A*(TA-TB)+TB*ALOG10(P2)-TA*ALOG10(P1)
00500 C=C4/(ALOG10(P1)-ALOG10(P2))
00510 B=(TA+C)*(A-ALOG10(P1))
00520 C=C+TD

```

(continued)

TABLE A-1. (Concluded)

```

00530 WRITE(6,8)NAME
00540 8 FORMAT(30X,A10,/,/,*, VAPOR PRESSURE CALCULATED FROM ANTOINE *,
00550+*EQUATION*,/,*, LOG VP = A - B/(C+T)*,/)
00560 WRITE(6,1)A,B,C,T1,T2,T3,IT,P1,P2,P3,IP
00570 1 FORMAT(2X,*A=*,E15.7,2X,*B=*,E15.7,2X,*C=*,E15.7,/,/,*, CALC FROM*
00580+*,* TEMP=*,3F12.3,* IN DEGREES *,A1,/,*, AND PRESSURE= *,3E12.5,
00590+*,* IN *,A8,/)
00600 DO 15 I=K,L,M
00610 T=I
00620 PP=A-B/(C+T)
00630 P=10**PP
00640 15 WRITE(6,9)T,IT,P,IP,PP
00650 9 FORMAT(* TEMP=*,F8.2,1X,A1,2X,*PRESSURE=*,E13.7,1X,A6,2X,
00660+*,* LOG P= *,F7.3,/)
00670 GO TO 25
00680 30 WRITE(6,18)
00690 18 FORMAT(* TEMP NOT IN "C", "K", "F", OR "R"*)
00700 25 WRITE(6,21)
00710 21 FORMAT(/)
00720 CALL EXIT
00730 END

```

TABLE A-2. Antoine Equation Constants

Metal	Derived From Vapor Pressures at Temperatures of 800, 1000, and 1200 K			Derived From Vapor Pressures at Temperatures of 1000, 1200, and 1400 K		
	A	B	C	A	B	C
Zinc	7.861609	5702.700	-34.88299	7.651451	5263.722	-76.32259
Magnesium	7.168599	5313.847	-127.8842	7.629302	6246.907	-46.82022
Chromium	11.93103	24233.08	96.71900	9.729311	19247.88	-32.49061
Iron	9.590333	19829.52	-34.28129	9.614180	19880.38	-32.92745
Nickel	11.02087	23440.51	27.33814	10.49116	22265.03	-0.9875404
Molybdenum	4.591283	23516.27	-166.2576	14.36286	45264.03	191.8722

TABLE A-3. Percent Deviation for Various Sets, Antoine Equation Empirical Constants

Temperature (°C)	Metal					
	Zn	Mg	Cr	Fe	Ni	Mo
760	-0.284	0.655	-2.51	0.0303	-0.590	11.1
770	-0.312	0.783	-3.024	0.0363	-0.704	13.11
780	-0.384	0.884	-3.361	0.0375	-0.798	14.52
790	-0.387	0.947	-3.687	0.0485	-0.871	15.8
800	-0.428	1.024	-3.910	0.0471	-0.958	16.63
810	-0.456	1.018	-4.053	0.0499	-0.985	17.05
820	-0.438	1.043	-4.109	0.0551	-0.958	16.43

NOTE: Percentage Deviation = $100 \left(\frac{P - P'}{P} \right)$

P = Vapor Pressure from Antoine equation using constants derived from 3 low-temperature data points.

P' = Vapor Pressure from Antoine equation using constants derived from 3 higher-temperature data points.

TABLE A-4.

CHROMIUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

$\text{LOG VP} = A - B/(C+T)$

A= .1193103E+02 B= .2423308E+05 C= .9671900E+02

CALC FROM TEMP= 800.000 1000.000 1200.000 IN DEGREES K
AND PRESSURE= .80700E-15 .68400E-10 .17500E-06 IN MM HG

TEMP= 800.00 K PRESSURE= .8070000E-15 MM HG LOG P= -15.093

TEMP= 825.00 K PRESSURE= .4363712E-14 MM HG LOG P= -14.360

TEMP= 850.00 K PRESSURE= .2158375E-13 MM HG LOG P= -13.666

TEMP= 875.00 K PRESSURE= .9832724E-13 MM HG LOG P= -13.007

TEMP= 900.00 K PRESSURE= .4151309E-12 MM HG LOG P= -12.382

TEMP= 925.00 K PRESSURE= .1633374E-11 MM HG LOG P= -11.787

(continued)

TABLE A-4. (Continued)

TEMP= 950.00 K	PRESSURE= .6019615E-11 MM HG	LOG P= -11.220
TEMP= 975.00 K	PRESSURE= .2087484E-10 MM HG	LOG P= -10.680
TEMP= 1000.00 K	PRESSURE= .6840000E-10 MM HG	LOG P= -10.165
TEMP= 1025.00 K	PRESSURE= .2125759E-09 MM HG	LOG P= -9.672
TEMP= 1050.00 K	PRESSURE= .6287810E-09 MM HG	LOG P= -9.202
TEMP= 1075.00 K	PRESSURE= .1775770E-08 MM HG	LOG P= -8.751
TEMP= 1100.00 K	PRESSURE= .4802149E-08 MM HG	LOG P= -8.319
TEMP= 1125.00 K	PRESSURE= .1246816E-07 MM HG	LOG P= -7.904
TEMP= 1150.00 K	PRESSURE= .3115667E-07 MM HG	LOG P= -7.506
TEMP= 1175.00 K	PRESSURE= .7510372E-07 MM HG	LOG P= -7.124
TEMP= 1200.00 K	PRESSURE= .1750000E-06 MM HG	LOG P= -6.757
TEMP= 1225.00 K	PRESSURE= .3949271E-06 MM HG	LOG P= -6.403
TEMP= 1250.00 K	PRESSURE= .8647134E-06 MM HG	LOG P= -6.063
TEMP= 1275.00 K	PRESSURE= .1840015E-05 MM HG	LOG P= -5.735
TEMP= 1300.00 K	PRESSURE= .3810925E-05 MM HG	LOG P= -5.419
TEMP= 1325.00 K	PRESSURE= .7693408E-05 MM HG	LOG P= -5.114
TEMP= 1350.00 K	PRESSURE= .1515874E-04 MM HG	LOG P= -4.819
TEMP= 1375.00 K	PRESSURE= .2918774E-04 MM HG	LOG P= -4.535
TEMP= 1400.00 K	PRESSURE= .5498353E-04 MM HG	LOG P= -4.260

(continued)

TABLE A-4. (Continued)

CHROMIUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .9729311E+01 B= .1924788E+05 C= -.3249061E+02

CALC FROM TEMP= 1000.000 1200.000 1400.000 IN DEGREES K
 AND PRESSURE= .68400E-10 .17500E-06 .45100E-04 IN MM HG

TEMP= 800.00 K	PRESSURE= .4476607E-15 MM HG	LOG P= -15.349
TEMP= 825.00 K	PRESSURE= .2767293E-14 MM HG	LOG P= -14.558
TEMP= 850.00 K	PRESSURE= .1530298E-13 MM HG	LOG P= -13.815
TEMP= 875.00 K	PRESSURE= .7645734E-13 MM HG	LOG P= -13.117
TEMP= 900.00 K	PRESSURE= .3481730E-12 MM HG	LOG P= -12.458
TEMP= 925.00 K	PRESSURE= .1456423E-11 MM HG	LOG P= -11.837
TEMP= 950.00 K	PRESSURE= .5635230E-11 MM HG	LOG P= -11.249
TEMP= 975.00 K	PRESSURE= .2029375E-10 MM HG	LOG P= -10.693
TEMP= 1000.00 K	PRESSURE= .6840000E-10 MM HG	LOG P= -10.165
TEMP= 1025.00 K	PRESSURE= .2168533E-09 MM HG	LOG P= -9.664
TEMP= 1050.00 K	PRESSURE= .6496085E-09 MM HG	LOG P= -9.187
TEMP= 1075.00 K	PRESSURE= .1846225E-08 MM HG	LOG P= -8.734
TEMP= 1100.00 K	PRESSURE= .4996549E-08 MM HG	LOG P= -8.301
TEMP= 1125.00 K	PRESSURE= .1292013E-07 MM HG	LOG P= -7.889
TEMP= 1150.00 K	PRESSURE= .3201868E-07 MM HG	LOG P= -7.495
TEMP= 1175.00 K	PRESSURE= .7625899E-07 MM HG	LOG P= -7.118
TEMP= 1200.00 K	PRESSURE= .1750000E-06 MM HG	LOG P= -6.757
TEMP= 1225.00 K	PRESSURE= .3878462E-06 MM HG	LOG P= -6.411
TEMP= 1250.00 K	PRESSURE= .8319307E-06 MM HG	LOG P= -6.080
TEMP= 1275.00 K	PRESSURE= .1730525E-05 MM HG	LOG P= -5.762

(continued)

TABLE A-4. (Continued)

TEMP= 1300.00 K	PRESSURE= .3497201E-05 MM HG	LOG P= -5.456
TEMP= 1325.00 K	PRESSURE= .6877705E-05 MM HG	LOG P= -5.163
TEMP= 1350.00 K	PRESSURE= .1318316E-04 MM HG	LOG P= -4.880
TEMP= 1375.00 K	PRESSURE= .2466446E-04 MM HG	LOG P= -4.608
TEMP= 1400.00 K	PRESSURE= .4510000E-04 MM HG	LOG P= -4.346

CHROMIUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .1193103E+02 B= .2423308E+05 C= .3698690E+03

CALC FROM TEMP=	526.850	726.850	926.850	IN DEGREES C
AND PRESSURE=	.80700E-15	.68400E-10	.17500E-06	IN MM HG

TEMP= 730.00 C	PRESSURE= .7912951E-10 MM HG	LOG P= -10.102
TEMP= 735.00 C	PRESSURE= .9955102E-10 MM HG	LOG P= -10.002
TEMP= 740.00 C	PRESSURE= .1249841E-09 MM HG	LOG P= -9.903
TEMP= 745.00 C	PRESSURE= .1565948E-09 MM HG	LOG P= -9.805
TEMP= 750.00 C	PRESSURE= .1958057E-09 MM HG	LOG P= -9.708
TEMP= 755.00 C	PRESSURE= .2443492E-09 MM HG	LOG P= -9.612
TEMP= 760.00 C	PRESSURE= .3043302E-09 MM HG	LOG P= -9.517
TEMP= 765.00 C	PRESSURE= .3783024E-09 MM HG	LOG P= -9.422
TEMP= 770.00 C	PRESSURE= .4693580E-09 MM HG	LOG P= -9.328
TEMP= 775.00 C	PRESSURE= .5812343E-09 MM HG	LOG P= -9.236
TEMP= 780.00 C	PRESSURE= .7184404E-09 MM HG	LOG P= -9.144
TEMP= 785.00 C	PRESSURE= .8864073E-09 MM HG	LOG P= -9.052
TEMP= 790.00 C	PRESSURE= .1091665E-08 MM HG	LOG P= -8.962

(continued)

TABLE A-4. (Continued)

TEMP=	795.00 C	PRESSURE=	.1342050E-08 MM HG	LOG P=	-8.872
TEMP=	800.00 C	PRESSURE=	.1646954E-08 MM HG	LOG P=	-8.783
TEMP=	805.00 C	PRESSURE=	.2017611E-08 MM HG	LOG P=	-8.695
TEMP=	810.00 C	PRESSURE=	.2467438E-08 MM HG	LOG P=	-8.608
TEMP=	815.00 C	PRESSURE=	.3012432E-08 MM HG	LOG P=	-8.521
TEMP=	820.00 C	PRESSURE=	.3671639E-08 MM HG	LOG P=	-8.435
TEMP=	825.00 C	PRESSURE=	.4467694E-08 MM HG	LOG P=	-8.350
TEMP=	830.00 C	PRESSURE=	.5427460E-08 MM HG	LOG P=	-8.265
TEMP=	835.00 C	PRESSURE=	.6582765E-08 MM HG	LOG P=	-8.182
TEMP=	840.00 C	PRESSURE=	.7971267E-08 MM HG	LOG P=	-8.098
TEMP=	845.00 C	PRESSURE=	.9637452E-08 MM HG	LOG P=	-8.016
TEMP=	850.00 C	PRESSURE=	.1163379E-07 MM HG	LOG P=	-7.934

CHROMIUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .9729311E+01 B= .1924788E+05 C= .2406594E+03

CALC FROM TEMP= 726.850 926.850 1126.850 IN DEGREES C
 AND PRESSURE= .68400E-10 .17500E-06 .45100E-04 IN MM HG

TEMP=	730.00 C	PRESSURE=	.7936285E-10 MM HG	LOG P=	-10.100
TEMP=	735.00 C	PRESSURE=	.1002858E-09 MM HG	LOG P=	-9.999
TEMP=	740.00 C	PRESSURE=	.1264227E-09 MM HG	LOG P=	-9.898
TEMP=	745.00 C	PRESSURE=	.1589975E-09 MM HG	LOG P=	-9.799
TEMP=	750.00 C	PRESSURE=	.1995035E-09 MM HG	LOG P=	-9.700
TEMP=	755.00 C	PRESSURE=	.2497588E-09 MM HG	LOG P=	-9.602

(continued)

TABLE A-4. (Continued)

TEMP=	760.00 C	PRESSURE=	.3119723E-09 MM HG	LOG P=	-9.506
TEMP=	765.00 C	PRESSURE=	.3888220E-09 MM HG	LOG P=	-9.410
TEMP=	770.00 C	PRESSURE=	.4835477E-09 MM HG	LOG P=	-9.316
TEMP=	775.00 C	PRESSURE=	.6000611E-09 MM HG	LOG P=	-9.222
TEMP=	780.00 C	PRESSURE=	.7430757E-09 MM HG	LOG P=	-9.129
TEMP=	785.00 C	PRESSURE=	.9182597E-09 MM HG	LOG P=	-9.037
TEMP=	790.00 C	PRESSURE=	.1132416E-08 MM HG	LOG P=	-8.946
TEMP=	795.00 C	PRESSURE=	.1393694E-08 MM HG	LOG P=	-8.856
TEMP=	800.00 C	PRESSURE=	.1711837E-08 MM HG	LOG P=	-8.767
TEMP=	805.00 C	PRESSURE=	.2098474E-08 MM HG	LOG P=	-8.678
TEMP=	810.00 C	PRESSURE=	.2567455E-08 MM HG	LOG P=	-8.590
TEMP=	815.00 C	PRESSURE=	.3135251E-08 MM HG	LOG P=	-8.504
TEMP=	820.00 C	PRESSURE=	.3821411E-08 MM HG	LOG P=	-8.418
TEMP=	825.00 C	PRESSURE=	.4649098E-08 MM HG	LOG P=	-8.333
TEMP=	830.00 C	PRESSURE=	.5645706E-08 MM HG	LOG P=	-8.248
TEMP=	835.00 C	PRESSURE=	.6843586E-08 MM HG	LOG P=	-8.165
TEMP=	840.00 C	PRESSURE=	.8280869E-08 MM HG	LOG P=	-8.082
TEMP=	845.00 C	PRESSURE=	.1000243E-07 MM HG	LOG P=	-8.000
TEMP=	850.00 C	PRESSURE=	.1206099E-07 MM HG	LOG P=	-7.919

(continued)

TABLE A-4. (Continued)

CHROMIUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

$$\log_{10} VP = A - B/(C+T)$$

A= .1193103E+02 B= .2423308E+05 C= .3698690E+03

CALC FROM TEMP= 526.850 726.850 926.850 IN DEGREES C
AND PRESSURE= .80700E-15 .68400E-10 .17500E-06 IN MM HG

TEMP=	781.00 C	PRESSURE=	.7493810E-09 MM HG	LOG P=	-9.125
TEMP=	782.00 C	PRESSURE=	.7815969E-09 MM HG	LOG P=	-9.107
TEMP=	783.00 C	PRESSURE=	.8151382E-09 MM HG	LOG P=	-9.089
TEMP=	784.00 C	PRESSURE=	.8500570E-09 MM HG	LOG P=	-9.071
TEMP=	785.00 C	PRESSURE=	.8864073E-09 MM HG	LOG P=	-9.052
TEMP=	786.00 C	PRESSURE=	.9242450E-09 MM HG	LOG P=	-9.034
TEMP=	787.00 C	PRESSURE=	.9636282E-09 MM HG	LOG P=	-9.016
TEMP=	788.00 C	PRESSURE=	.1004617E-08 MM HG	LOG P=	-8.998
TEMP=	789.00 C	PRESSURE=	.1047274E-08 MM HG	LOG P=	-8.980
TEMP=	790.00 C	PRESSURE=	.1091665E-08 MM HG	LOG P=	-8.962
TEMP=	791.00 C	PRESSURE=	.1137855E-08 MM HG	LOG P=	-8.944
TEMP=	792.00 C	PRESSURE=	.1185915E-08 MM HG	LOG P=	-8.926
TEMP=	793.00 C	PRESSURE=	.1235917E-08 MM HG	LOG P=	-8.908
TEMP=	794.00 C	PRESSURE=	.1287936E-08 MM HG	LOG P=	-8.890
TEMP=	795.00 C	PRESSURE=	.1342050E-08 MM HG	LOG P=	-8.872
TEMP=	796.00 C	PRESSURE=	.1398338E-08 MM HG	LOG P=	-8.854
TEMP=	797.00 C	PRESSURE=	.1456884E-08 MM HG	LOG P=	-8.837
TEMP=	798.00 C	PRESSURE=	.1517776E-08 MM HG	LOG P=	-8.819
TEMP=	799.00 C	PRESSURE=	.1581101E-08 MM HG	LOG P=	-8.801
TEMP=	800.00 C	PRESSURE=	.1646954E-08 MM HG	LOG P=	-8.783

(continued)

TABLE A-4. (Concluded)

TEMP=	801.00 C	PRESSURE=	.1715429E-08 MM HG	LOG P=	-8.766
TEMP=	802.00 C	PRESSURE=	.1786628E-08 MM HG	LOG P=	-8.748
TEMP=	803.00 C	PRESSURE=	.1860652E-08 MM HG	LOG P=	-8.730
TEMP=	804.00 C	PRESSURE=	.1937609E-08 MM HG	LOG P=	-8.713
TEMP=	805.00 C	PRESSURE=	.2017611E-08 MM HG	LOG P=	-8.695

TABLE A-5.

IRON

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .9590333E+01 B= .1982952E+05 C= -.3428129E+02

CALC FROM TEMP= 800.000 1000.000 1200.000 IN DEGREES K
 AND PRESSURE= .49400E-16 .11400E-10 .38000E-07 IN MM HG

TEMP=	800.00 K	PRESSURE=	.4940000E-16 MM HG	LOG P=	-16.306
TEMP=	825.00 K	PRESSURE=	.3254580E-15 MM HG	LOG P=	-15.488
TEMP=	850.00 K	PRESSURE=	.1910187E-14 MM HG	LOG P=	-14.719
TEMP=	875.00 K	PRESSURE=	.1009130E-13 MM HG	LOG P=	-13.996
TEMP=	900.00 K	PRESSURE=	.4842491E-13 MM HG	LOG P=	-13.315
TEMP=	925.00 K	PRESSURE=	.2127923E-12 MM HG	LOG P=	-12.672
TEMP=	950.00 K	PRESSURE=	.8624625E-12 MM HG	LOG P=	-12.064
TEMP=	975.00 K	PRESSURE=	.3245042E-11 MM HG	LOG P=	-11.489
TEMP=	1000.00 K	PRESSURE=	.1140000E-10 MM HG	LOG P=	-10.943
TEMP=	1025.00 K	PRESSURE=	.3758203E-10 MM HG	LOG P=	-10.425
TEMP=	1050.00 K	PRESSURE=	.1168660E-09 MM HG	LOG P=	-9.932

(continued)

TABLE A-5. (Continued)

TEMP= 1075.00 K	PRESSURE= .3440791E-09 MM HG	LOG P= -9.463
TEMP= 1100.00 K	PRESSURE= .9629995E-09 MM HG	LOG P= -9.016
TEMP= 1125.00 K	PRESSURE= .2571012E-08 MM HG	LOG P= -8.590
TEMP= 1150.00 K	PRESSURE= .6568558E-08 MM HG	LOG P= -8.183
TEMP= 1175.00 K	PRESSURE= .1610572E-07 MM HG	LOG P= -7.793
TEMP= 1200.00 K	PRESSURE= .3800000E-07 MM HG	LOG P= -7.420
TEMP= 1225.00 K	PRESSURE= .8648333E-07 MM HG	LOG P= -7.063
TEMP= 1250.00 K	PRESSURE= .1902797E-06 MM HG	LOG P= -6.721
TEMP= 1275.00 K	PRESSURE= .4055566E-06 MM HG	LOG P= -6.392
TEMP= 1300.00 K	PRESSURE= .8389335E-06 MM HG	LOG P= -6.076
TEMP= 1325.00 K	PRESSURE= .1687232E-05 MM HG	LOG P= -5.773
TEMP= 1350.00 K	PRESSURE= .3304384E-05 MM HG	LOG P= -5.481
TEMP= 1375.00 K	PRESSURE= .6311313E-05 MM HG	LOG P= -5.200
TEMP= 1400.00 K	PRESSURE= .1177227E-04 MM HG	LOG P= -4.929

IRON

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

$$\text{LOG VP} = A - B/(C+T)$$

A= .9614180E+01 B= .1988038E+05 C= -.3292745E+02

CALC FROM TEMP= 1000.000 1200.000 1400.000 IN DEGREES K
AND PRESSURE= .11400E-10 .38000E-07 .11800E-04 IN MM HG

TEMP= 800.00 K	PRESSURE= .4977084E-16 MM HG	LOG P= -16.303
TEMP= 825.00 K	PRESSURE= .3273359E-15 MM HG	LOG P= -15.485
TEMP= 850.00 K	PRESSURE= .1918467E-14 MM HG	LOG P= -14.717
TEMP= 875.00 K	PRESSURE= .1012315E-13 MM HG	LOG P= -13.995

(continued)

TABLE A-5. (Continued)

TEMP= 900.00 K	PRESSURE= .4853130E-13 MM HG	LOG P= -13.314
TEMP= 925.00 K	PRESSURE= .2130958E-12 MM HG	LOG P= -12.671
TEMP= 950.00 K	PRESSURE= .8631677E-12 MM HG	LOG P= -12.064
TEMP= 975.00 K	PRESSURE= .3246173E-11 MM HG	LOG P= -11.489
TEMP= 1000.00 K	PRESSURE= .1140000E-10 MM HG	LOG P= -10.943
TEMP= 1025.00 K	PRESSURE= .3757885E-10 MM HG	LOG P= -10.425
TEMP= 1050.00 K	PRESSURE= .1168194E-09 MM HG	LOG P= -9.932
TEMP= 1075.00 K	PRESSURE= .3439158E-09 MM HG	LOG P= -9.464
TEMP= 1100.00 K	PRESSURE= .9625346E-09 MM HG	LOG P= -9.017
TEMP= 1125.00 K	PRESSURE= .2569902E-08 MM HG	LOG P= -8.590
TEMP= 1150.00 K	PRESSURE= .6566368E-08 MM HG	LOG P= -8.183
TEMP= 1175.00 K	PRESSURE= .1610275E-07 MM HG	LOG P= -7.793
TEMP= 1200.00 K	PRESSURE= .3800000E-07 MM HG	LOG P= -7.420
TEMP= 1225.00 K	PRESSURE= .8650215E-07 MM HG	LOG P= -7.063
TEMP= 1250.00 K	PRESSURE= .1903680E-06 MM HG	LOG P= -6.720
TEMP= 1275.00 K	PRESSURE= .4058548E-06 MM HG	LOG P= -6.392
TEMP= 1300.00 K	PRESSURE= .8397956E-06 MM HG	LOG P= -6.076
TEMP= 1325.00 K	PRESSURE= .1689490E-05 MM HG	LOG P= -5.772
TEMP= 1350.00 K	PRESSURE= .3309886E-05 MM HG	LOG P= -5.480
TEMP= 1375.00 K	PRESSURE= .6323965E-05 MM HG	LOG P= -5.199
TEMP= 1400.00 K	PRESSURE= .1180000E-04 MM HG	LOG P= -4.928

(continued)

TABLE A-5. (Continued)

IRON

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

 $\log VP = A - B/(C+T)$

A= .9590333E+01 B= .1982952E+05 C= .2388687E+03

CALC FROM TEMP= 526.850 726.850 926.850 IN DEGREES C
AND PRESSURE= .49400E-16 .11400E-10 .38000E-07 IN MM HG

TEMP=	730.00 C	PRESSURE=	.1329424E-10 MM HG	LOG P=	-10.876
TEMP=	735.00 C	PRESSURE=	.1693334E-10 MM HG	LOG P=	-10.771
TEMP=	740.00 C	PRESSURE=	.2151535E-10 MM HG	LOG P=	-10.667
TEMP=	745.00 C	PRESSURE=	.2727074E-10 MM HG	LOG P=	-10.564
TEMP=	750.00 C	PRESSURE=	.3448296E-10 MM HG	LOG P=	-10.462
TEMP=	755.00 C	PRESSURE=	.4349974E-10 MM HG	LOG P=	-10.362
TEMP=	760.00 C	PRESSURE=	.5474682E-10 MM HG	LOG P=	-10.262
TEMP=	765.00 C	PRESSURE=	.6874423E-10 MM HG	LOG P=	-10.163
TEMP=	770.00 C	PRESSURE=	.8612585E-10 MM HG	LOG P=	-10.065
TEMP=	775.00 C	PRESSURE=	.1076627E-09 MM HG	LOG P=	-9.968
TEMP=	780.00 C	PRESSURE=	.1342906E-09 MM HG	LOG P=	-9.872
TEMP=	785.00 C	PRESSURE=	.1671431E-09 MM HG	LOG P=	-9.777
TEMP=	790.00 C	PRESSURE=	.2075905E-09 MM HG	LOG P=	-9.683
TEMP=	795.00 C	PRESSURE=	.2572861E-09 MM HG	LOG P=	-9.590
TEMP=	800.00 C	PRESSURE=	.3182203E-09 MM HG	LOG P=	-9.497
TEMP=	805.00 C	PRESSURE=	.3927852E-09 MM HG	LOG P=	-9.406
TEMP=	810.00 C	PRESSURE=	.4838499E-09 MM HG	LOG P=	-9.315
TEMP=	815.00 C	PRESSURE=	.5948493E-09 MM HG	LOG P=	-9.226
TEMP=	820.00 C	PRESSURE=	.7298878E-09 MM HG	LOG P=	-9.137
TEMP=	825.00 C	PRESSURE=	.8938614E-09 MM HG	LOG P=	-9.049

(continued)

TABLE A-5. (Continued)

TEMP=	830.00 C	PRESSURE=	.1092599E-08 MM HG	LOG P=	-8.962
TEMP=	835.00 C	PRESSURE=	.1333029E-08 MM HG	LOG P=	-8.875
TEMP=	840.00 C	PRESSURE=	.1623370E-08 MM HG	LOG P=	-8.790
TEMP=	845.00 C	PRESSURE=	.1973358E-08 MM HG	LOG P=	-8.705
TEMP=	850.00 C	PRESSURE=	.2394505E-08 MM HG	LOG P=	-8.621

IRON

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .9614180E+01 B= .1988038E+05 C= .2402225E+03

CALC FROM TEMP=	724.850	924.850	1126.850	IN DEGREES C
AND PRESSURE=	.11400E-10	.38000E-07	.11800E-04	IN MM HG

TEMP=	730.00 C	PRESSURE=	.1329376E-10 MM HG	LOG P=	-10.876
TEMP=	735.00 C	PRESSURE=	.1693181E-10 MM HG	LOG P=	-10.771
TEMP=	740.00 C	PRESSURE=	.2151232E-10 MM HG	LOG P=	-10.667
TEMP=	745.00 C	PRESSURE=	.2726565E-10 MM HG	LOG P=	-10.564
TEMP=	750.00 C	PRESSURE=	.3447504E-10 MM HG	LOG P=	-10.462
TEMP=	755.00 C	PRESSURE=	.4348806E-10 MM HG	LOG P=	-10.362
TEMP=	760.00 C	PRESSURE=	.5473018E-10 MM HG	LOG P=	-10.262
TEMP=	765.00 C	PRESSURE=	.6872114E-10 MM HG	LOG P=	-10.163
TEMP=	770.00 C	PRESSURE=	.8609445E-10 MM HG	LOG P=	-10.065
TEMP=	775.00 C	PRESSURE=	.1076207E-09 MM HG	LOG P=	-9.968
TEMP=	780.00 C	PRESSURE=	.1342352E-09 MM HG	LOG P=	-9.872
TEMP=	785.00 C	PRESSURE=	.1670710E-09 MM HG	LOG P=	-9.777

(continued)

TABLE A-5. (Continued)

TEMP=	790.00 C	PRESSURE=	.2074976E-09 MM HG	LOG P=	-9.683
TEMP=	795.00 C	PRESSURE=	.2571675E-09 MM HG	LOG P=	-9.590
TEMP=	800.00 C	PRESSURE=	.3180703E-09 MM HG	LOG P=	-9.497
TEMP=	805.00 C	PRESSURE=	.3925970E-09 MM HG	LOG P=	-9.406
TEMP=	810.00 C	PRESSURE=	.4836156E-09 MM HG	LOG P=	-9.315
TEMP=	815.00 C	PRESSURE=	.5945598E-09 MM HG	LOG P=	-9.226
TEMP=	820.00 C	PRESSURE=	.7295326E-09 MM HG	LOG P=	-9.137
TEMP=	825.00 C	PRESSURE=	.8934285E-09 MM HG	LOG P=	-9.049
TEMP=	830.00 C	PRESSURE=	.1092075E-08 MM HG	LOG P=	-8.962
TEMP=	835.00 C	PRESSURE=	.1332399E-08 MM HG	LOG P=	-8.875
TEMP=	840.00 C	PRESSURE=	.1622618E-08 MM HG	LOG P=	-8.790
TEMP=	845.00 C	PRESSURE=	.1972468E-08 MM HG	LOG P=	-8.705
TEMP=	850.00 C	PRESSURE=	.2393457E-08 MM HG	LOG P=	-8.621

IRON

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .9590333E+01 B= .1982952E+05 C= .2388687E+03

CALC FROM TEMP= 526.850 726.850 926.850 IN DEGREES C
AND PRESSURE= .49400E-16 .11400E-10 .38000E-07 IN MM HG

TEMP=	781.00 C	PRESSURE=	.1403229E-09 MM HG	LOG P=	-9.853
TEMP=	782.00 C	PRESSURE=	.1466136E-09 MM HG	LOG P=	-9.834
TEMP=	783.00 C	PRESSURE=	.1531732E-09 MM HG	LOG P=	-9.815
TEMP=	784.00 C	PRESSURE=	.1600126E-09 MM HG	LOG P=	-9.796

(continued)

TABLE A-5. (Concluded)

TEMP=	785.00 C	PRESSURE=	.1671431E-09 MM HG	LOG P=	-9.777
TEMP=	786.00 C	PRESSURE=	.1745765E-09 MM HG	LOG P=	-9.758
TEMP=	787.00 C	PRESSURE=	.1823250E-09 MM HG	LOG P=	-9.739
TEMP=	788.00 C	PRESSURE=	.1904013E-09 MM HG	LOG P=	-9.720
TEMP=	789.00 C	PRESSURE=	.1988186E-09 MM HG	LOG P=	-9.702
TEMP=	790.00 C	PRESSURE=	.2075905E-09 MM HG	LOG P=	-9.683
TEMP=	791.00 C	PRESSURE=	.2167313E-09 MM HG	LOG P=	-9.664
TEMP=	792.00 C	PRESSURE=	.2262557E-09 MM HG	LOG P=	-9.645
TEMP=	793.00 C	PRESSURE=	.2361790E-09 MM HG	LOG P=	-9.627
TEMP=	794.00 C	PRESSURE=	.2465169E-09 MM HG	LOG P=	-9.608
TEMP=	795.00 C	PRESSURE=	.2572861E-09 MM HG	LOG P=	-9.590
TEMP=	796.00 C	PRESSURE=	.2685035E-09 MM HG	LOG P=	-9.571
TEMP=	797.00 C	PRESSURE=	.2801869E-09 MM HG	LOG P=	-9.553
TEMP=	798.00 C	PRESSURE=	.2923547E-09 MM HG	LOG P=	-9.534
TEMP=	799.00 C	PRESSURE=	.3050259E-09 MM HG	LOG P=	-9.516
TEMP=	800.00 C	PRESSURE=	.3182203E-09 MM HG	LOG P=	-9.497
TEMP=	801.00 C	PRESSURE=	.3319584E-09 MM HG	LOG P=	-9.479
TEMP=	802.00 C	PRESSURE=	.3462615E-09 MM HG	LOG P=	-9.461
TEMP=	803.00 C	PRESSURE=	.3611516E-09 MM HG	LOG P=	-9.442
TEMP=	804.00 C	PRESSURE=	.3766516E-09 MM HG	LOG P=	-9.424
TEMP=	805.00 C	PRESSURE=	.3927852E-09 MM HG	LOG P=	-9.406

TABLE A-6.

MAGNESIUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

$$\text{LOG VP} = A - B/(C+T)$$

A= .7168599E+01 B= .5313847E+04 C= -.1278842E+03

CALC FROM TEMP= 800.000 1000.000 1200.000 IN DEGREES K
AND PRESSURE= .18300E+00 .11900E+02 .16300E+03 IN MM HG

TEMP= 800.00 K	PRESSURE= .1830000E+00 MM HG	LOG P= -.738
TEMP= 825.00 K	PRESSURE= .3515457E+00 MM HG	LOG P= -.454
TEMP= 850.00 K	PRESSURE= .6454765E+00 MM HG	LOG P= -.190
TEMP= 875.00 K	PRESSURE= .1137936E+01 MM HG	LOG P= .056
TEMP= 900.00 K	PRESSURE= .1933793E+01 MM HG	LOG P= .286
TEMP= 925.00 K	PRESSURE= .3178751E+01 MM HG	LOG P= .502
TEMP= 950.00 K	PRESSURE= .5069622E+01 MM HG	LOG P= .705
TEMP= 975.00 K	PRESSURE= .7865555E+01 MM HG	LOG P= .896
TEMP= 1000.00 K	PRESSURE= .1190000E+02 MM HG	LOG P= 1.076
TEMP= 1025.00 K	PRESSURE= .1759311E+02 MM HG	LOG P= 1.245
TEMP= 1050.00 K	PRESSURE= .2546427E+02 MM HG	LOG P= 1.406
TEMP= 1075.00 K	PRESSURE= .3614450E+02 MM HG	LOG P= 1.558
TEMP= 1100.00 K	PRESSURE= .5038827E+02 MM HG	LOG P= 1.702
TEMP= 1125.00 K	PRESSURE= .6908464E+02 MM HG	LOG P= 1.839
TEMP= 1150.00 K	PRESSURE= .9326726E+02 MM HG	LOG P= 1.970
TEMP= 1175.00 K	PRESSURE= .1241231E+03 MM HG	LOG P= 2.094
TEMP= 1200.00 K	PRESSURE= .1630000E+03 MM HG	LOG P= 2.212
TEMP= 1225.00 K	PRESSURE= .2114119E+03 MM HG	LOG P= 2.325
TEMP= 1250.00 K	PRESSURE= .2710433E+03 MM HG	LOG P= 2.433
TEMP= 1275.00 K	PRESSURE= .3437515E+03 MM HG	LOG P= 2.536

(continued)

TABLE A-6. (Continued)

TEMP= 1300.00 K	PRESSURE= .4315666E+03 MM HG	LOG P= 2.635
TEMP= 1325.00 K	PRESSURE= .5366910E+03 MM HG	LOG P= 2.730
TEMP= 1350.00 K	PRESSURE= .6614963E+03 MM HG	LOG P= 2.821
TEMP= 1375.00 K	PRESSURE= .8085185E+03 MM HG	LOG P= 2.908
TEMP= 1400.00 K	PRESSURE= .9804526E+03 MM HG	LOG P= 2.991

MAGNESIUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION
 $\text{LOG VP} = A - B/(C+T)$

A= .7629302E+01 B= .6246907E+04 C= -.4682022E+02

CALC FROM TEMP= 1000.000 1200.000 1400.000 IN DEGREES K
 AND PRESSURE= .11900E+02 .16300E+03 .10300E+04 IN MM HG

TEMP= 800.00 K	PRESSURE= .2164000E+00 MM HG	LOG P= -.665
TEMP= 825.00 K	PRESSURE= .3996813E+00 MM HG	LOG P= -.398
TEMP= 850.00 K	PRESSURE= .7105306E+00 MM HG	LOG P= -.148
TEMP= 875.00 K	PRESSURE= .1220018E+01 MM HG	LOG P= .086
TEMP= 900.00 K	PRESSURE= .2029507E+01 MM HG	LOG P= .307
TEMP= 925.00 K	PRESSURE= .3279673E+01 MM HG	LOG P= .516
TEMP= 950.00 K	PRESSURE= .5160970E+01 MM HG	LOG P= .713
TEMP= 975.00 K	PRESSURE= .7925474E+01 MM HG	LOG P= .899
TEMP= 1000.00 K	PRESSURE= .1190000E+02 MM HG	LOG P= 1.026
TEMP= 1025.00 K	PRESSURE= .1750031E+02 MM HG	LOG P= 1.243
TEMP= 1050.00 K	PRESSURE= .2524620E+02 MM HG	LOG P= 1.402
TEMP= 1075.00 K	PRESSURE= .3577725E+02 MM HG	LOG P= 1.554
TEMP= 1100.00 K	PRESSURE= .4986888E+02 MM HG	LOG P= 1.698

(continued)

TABLE A-6. (Continued)

TEMP= 1125.00 K	PRESSURE= .6844851E+02 MM HG	LOG P= 1.835
TEMP= 1150.00 K	PRESSURE= .9261149E+02 MM HG	LOG P= 1.967
TEMP= 1175.00 K	PRESSURE= .1236365E+03 MM HG	LOG P= 2.092
TEMP= 1200.00 K	PRESSURE= .1630000E+03 MM HG	LOG P= 2.212
TEMP= 1225.00 K	PRESSURE= .2123901E+03 MM HG	LOG P= 2.327
TEMP= 1250.00 K	PRESSURE= .2737185E+03 MM HG	LOG P= 2.437
TEMP= 1275.00 K	PRESSURE= .3491315E+03 MM HG	LOG P= 2.543
TEMP= 1300.00 K	PRESSURE= .4410188E+03 MM HG	LOG P= 2.644
TEMP= 1325.00 K	PRESSURE= .5520216E+03 MM HG	LOG P= 2.742
TEMP= 1350.00 K	PRESSURE= .6850372E+03 MM HG	LOG P= 2.836
TEMP= 1375.00 K	PRESSURE= .8432234E+03 MM HG	LOG P= 2.926
TEMP= 1400.00 K	PRESSURE= .1030000E+04 MM HG	LOG P= 3.013

MAGNESIUM

VAPOR PRESSURE CALCULATED FROM ANTUINE EQUATION

LOG VP = A - B/(C+T)

A=	.7168599E+01	B=	.5313847E+04	C=	.1452658E+03
CALC FROM TEMP=	526.850	726.850	926.850	IN DEGREES C	
AND PRESSURE=	.18300E+00	.11900E+02	.16300E+03	IN MM HG	
TEMP=	730.00 C	PRESSURE=	.1251628E+02 MM HG	LOG P=	1.097
TEMP=	735.00 C	PRESSURE=	.1355064E+02 MM HG	LOG P=	1.132
TEMP=	740.00 C	PRESSURE=	.1465733E+02 MM HG	LOG P=	1.166
TEMP=	745.00 C	PRESSURE=	.1584043E+02 MM HG	LOG P=	1.200
TEMP=	750.00 C	PRESSURE=	.1710419E+02 MM HG	LOG P=	1.233
TEMP=	755.00 C	PRESSURE=	.1845304E+02 MM HG	LOG P=	1.266

(continued)

TABLE A-6. (Continued)

TEMP=	760.00 C	PRESSURE=	.1989156E+02 MM HG	LOG P=	1.299
TEMP=	765.00 C	PRESSURE=	.2142456E+02 MM HG	LOG P=	1.331
TEMP=	770.00 C	PRESSURE=	.2305699E+02 MM HG	LOG P=	1.363
TEMP=	775.00 C	PRESSURE=	.2479400E+02 MM HG	LOG P=	1.394
TEMP=	780.00 C	PRESSURE=	.2664096E+02 MM HG	LOG P=	1.426
TEMP=	785.00 C	PRESSURE=	.2860340E+02 MM HG	LOG P=	1.456
TEMP=	790.00 C	PRESSURE=	.3068707E+02 MM HG	LOG P=	1.487
TEMP=	795.00 C	PRESSURE=	.3289791E+02 MM HG	LOG P=	1.517
TEMP=	800.00 C	PRESSURE=	.3524209E+02 MM HG	LOG P=	1.547
TEMP=	805.00 C	PRESSURE=	.3772597E+02 MM HG	LOG P=	1.577
TEMP=	810.00 C	PRESSURE=	.4035614E+02 MM HG	LOG P=	1.606
TEMP=	815.00 C	PRESSURE=	.4313938E+02 MM HG	LOG P=	1.635
TEMP=	820.00 C	PRESSURE=	.4608273E+02 MM HG	LOG P=	1.664
TEMP=	825.00 C	PRESSURE=	.4919342E+02 MM HG	LOG P=	1.692
TEMP=	830.00 C	PRESSURE=	.5247892E+02 MM HG	LOG P=	1.720
TEMP=	835.00 C	PRESSURE=	.5594695E+02 MM HG	LOG P=	1.748
TEMP=	840.00 C	PRESSURE=	.5960544E+02 MM HG	LOG P=	1.775
TEMP=	845.00 C	PRESSURE=	.6346255E+02 MM HG	LOG P=	1.803
TEMP=	850.00 C	PRESSURE=	.6752670E+02 MM HG	LOG P=	1.829

(continued)

TABLE A-6. (Continued)

MAGNESIUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

 $\text{LOG VP} = A - B/(C+T)$

A= .7629302E+01 B= .6246907E+04 C= .2263298E+03

CALC FROM TEMP= 726.850 926.850 1126.850 IN DEGREES C
 AND PRESSURE= .11900E+02 .16300E+03 .10300E+04 IN MM HG

TEMP=	730.00 C	PRESSURE=	.1250645E+02 MM HG	LOG P=	1.097
TEMP=	735.00 C	PRESSURE=	.1352411E+02 MM HG	LOG P=	1.131
TEMP=	740.00 C	PRESSURE=	.1461274E+02 MM HG	LOG P=	1.165
TEMP=	745.00 C	PRESSURE=	.1577643E+02 MM HG	LOG P=	1.198
TEMP=	750.00 C	PRESSURE=	.1701942E+02 MM HG	LOG P=	1.231
TEMP=	755.00 C	PRESSURE=	.1834616E+02 MM HG	LOG P=	1.264
TEMP=	760.00 C	PRESSURE=	.1976128E+02 MM HG	LOG P=	1.296
TEMP=	765.00 C	PRESSURE=	.2126961E+02 MM HG	LOG P=	1.328
TEMP=	770.00 C	PRESSURE=	.2287617E+02 MM HG	LOG P=	1.359
TEMP=	775.00 C	PRESSURE=	.2458619E+02 MM HG	LOG P=	1.391
TEMP=	780.00 C	PRESSURE=	.2640511E+02 MM HG	LOG P=	1.422
TEMP=	785.00 C	PRESSURE=	.2833860E+02 MM HG	LOG P=	1.452
TEMP=	790.00 C	PRESSURE=	.3039252E+02 MM HG	LOG P=	1.483
TEMP=	795.00 C	PRESSURE=	.3257299E+02 MM HG	LOG P=	1.513
TEMP=	800.00 C	PRESSURE=	.3488633E+02 MM HG	LOG P=	1.543
TEMP=	805.00 C	PRESSURE=	.3733911E+02 MM HG	LOG P=	1.572
TEMP=	810.00 C	PRESSURE=	.3993816E+02 MM HG	LOG P=	1.601
TEMP=	815.00 C	PRESSURE=	.4269051E+02 MM HG	LOG P=	1.630
TEMP=	820.00 C	PRESSURE=	.4560349E+02 MM HG	LOG P=	1.659
TEMP=	825.00 C	PRESSURE=	.4868466E+02 MM HG	LOG P=	1.687

(continued)

TABLE A-6. (Continued)

TEMP=	830.00 C	PRESSURE=	.5194185E+02 MM HG	LOG P=	1.716
TEMP=	835.00 C	PRESSURE=	.5538315E+02 MM HG	LOG P=	1.743
TEMP=	840.00 C	PRESSURE=	.5901693E+02 MM HG	LOG P=	1.771
TEMP=	845.00 C	PRESSURE=	.6285184E+02 MM HG	LOG P=	1.798
TEMP=	850.00 C	PRESSURE=	.6689680E+02 MM HG	LOG P=	1.825

MAGNESIUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .7168599E+01 B= .5313847E+04 C= .1452658E+03

CALC FROM TEMP=	526.850	726.850	926.850 IN DEGREES C
AND PRESSURE=	.18300E+00	.11900E+02	.16300E+03 IN MM HG

TEMP=	781.00 C	PRESSURE=	.2702403E+02 MM HG	LOG P=	1.432
TEMP=	782.00 C	PRESSURE=	.2741176E+02 MM HG	LOG P=	1.438
TEMP=	783.00 C	PRESSURE=	.2780420E+02 MM HG	LOG P=	1.444
TEMP=	784.00 C	PRESSURE=	.2820140E+02 MM HG	LOG P=	1.450
TEMP=	785.00 C	PRESSURE=	.2860340E+02 MM HG	LOG P=	1.456
TEMP=	786.00 C	PRESSURE=	.2901025E+02 MM HG	LOG P=	1.463
TEMP=	787.00 C	PRESSURE=	.2942199E+02 MM HG	LOG P=	1.469
TEMP=	788.00 C	PRESSURE=	.2983868E+02 MM HG	LOG P=	1.475
TEMP=	789.00 C	PRESSURE=	.3026035E+02 MM HG	LOG P=	1.481
TEMP=	790.00 C	PRESSURE=	.3068707E+02 MM HG	LOG P=	1.487
TEMP=	791.00 C	PRESSURE=	.3111887E+02 MM HG	LOG P=	1.493
TEMP=	792.00 C	PRESSURE=	.3155580E+02 MM HG	LOG P=	1.499
TEMP=	793.00 C	PRESSURE=	.3199792E+02 MM HG	LOG P=	1.505

(continued)

TABLE A-6. (Concluded)

TEMP=	794.00 C	PRESSURE=	.3244528E+02 MM HG	LOG P=	1.511
TEMP=	795.00 C	PRESSURE=	.3289791E+02 MM HG	LOG P=	1.517
TEMP=	796.00 C	PRESSURE=	.3335588E+02 MM HG	LOG P=	1.523
TEMP=	797.00 C	PRESSURE=	.3381923E+02 MM HG	LOG P=	1.529
TEMP=	798.00 C	PRESSURE=	.3428802E+02 MM HG	LOG P=	1.535
TEMP=	799.00 C	PRESSURE=	.3476229E+02 MM HG	LOG P=	1.541
TEMP=	800.00 C	PRESSURE=	.3524209E+02 MM HG	LOG P=	1.547
TEMP=	801.00 C	PRESSURE=	.3572749E+02 MM HG	LOG P=	1.553
TEMP=	802.00 C	PRESSURE=	.3621852E+02 MM HG	LOG P=	1.559
TEMP=	803.00 C	PRESSURE=	.3671524E+02 MM HG	LOG P=	1.565
TEMP=	804.00 C	PRESSURE=	.3721771E+02 MM HG	LOG P=	1.571
TEMP=	805.00 C	PRESSURE=	.3772597E+02 MM HG	LOG P=	1.577

TABLE A-7.

MOLYBDENUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

$$\text{LOG VP} = A - B/(C+T)$$

$$A = .4591283E+01 \quad B = .2351627E+05 \quad C = -.1662576E+03$$

CALC FROM TEMP=	800.000	1000.000	1200.000	IN DEGREES K
AND PRESSURE=	.30500E-32	.24300E-23	.69600E-18	IN MM HG

TEMP=	800.00 K	PRESSURE=	.3050000E-32 MM HG	LOG P=	-32.516
TEMP=	825.00 K	PRESSURE=	.7808196E-31 MM HG	LOG P=	-31.107
TEMP=	850.00 K	PRESSURE=	.1576959E-29 MM HG	LOG P=	-29.802
TEMP=	875.00 K	PRESSURE=	.2576361E-28 MM HG	LOG P=	-28.589

(continued)

TABLE A-7. (Continued)

TEMP= 900.00 K	PRESSURE= .3479541E-27 MM HG	LOG P= -27.458
TEMP= 925.00 K	PRESSURE= .3958565E-26 MM HG	LOG P= -26.402
TEMP= 950.00 K	PRESSURE= .3856414E-25 MM HG	LOG P= -25.414
TEMP= 975.00 K	PRESSURE= .3263676E-24 MM HG	LOG P= -24.486
TEMP= 1000.00 K	PRESSURE= .2430000E-23 MM HG	LOG P= -23.614
TEMP= 1025.00 K	PRESSURE= .1609680E-22 MM HG	LOG P= -22.793
TEMP= 1050.00 K	PRESSURE= .9581092E-22 MM HG	LOG P= -22.019
TEMP= 1075.00 K	PRESSURE= .5169720E-21 MM HG	LOG P= -21.287
TEMP= 1100.00 K	PRESSURE= .2548702E-20 MM HG	LOG P= -20.594
TEMP= 1125.00 K	PRESSURE= .1156213E-19 MM HG	LOG P= -19.937
TEMP= 1150.00 K	PRESSURE= .4857111E-19 MM HG	LOG P= -19.314
TEMP= 1175.00 K	PRESSURE= .1900296E-18 MM HG	LOG P= -18.721
TEMP= 1200.00 K	PRESSURE= .6960000E-18 MM HG	LOG P= -18.157
TEMP= 1225.00 K	PRESSURE= .2397573E-17 MM HG	LOG P= -17.620
TEMP= 1250.00 K	PRESSURE= .7801026E-17 MM HG	LOG P= -17.108
TEMP= 1275.00 K	PRESSURE= .2406718E-16 MM HG	LOG P= -16.619
TEMP= 1300.00 K	PRESSURE= .7065143E-16 MM HG	LOG P= -16.151
TEMP= 1325.00 K	PRESSURE= .1979864E-15 MM HG	LOG P= -15.703
TEMP= 1350.00 K	PRESSURE= .5311870E-15 MM HG	LOG P= -15.275
TEMP= 1375.00 K	PRESSURE= .1368138E-14 MM HG	LOG P= -14.864
TEMP= 1400.00 K	PRESSURE= .3391253E-14 MM HG	LOG P= -14.470

(continued)

TABLE A-7. (Continued)

MOLYBDENUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .1436286E+02 B= .4526403E+05 C= .1918722E+03

CALC FROM TEMP=	1000.000	1200.000	1400.000	IN DEGREES K
AND PRESSURE=	.24300E-23	.69600E-18	.84800E-14	IN MM HG

TEMP= 800.00 K PRESSURE= .5344602E-31 MM HG LOG P= -31.272

TEMP= 825.00 K PRESSURE= .7077165E-30 MM HG LOG P= -30.150

TEMP= 850.00 K PRESSURE= .8278670E-29 MM HG LOG P= -29.082

TEMP= 875.00 K PRESSURE= .8629870E-28 MM HG LOG P= -28.064

TEMP= 900.00 K PRESSURE= .8080323E-27 MM HG LOG P= -27.093

TEMP= 925.00 K PRESSURE= .6844861E-26 MM HG LOG P= -26.165

TEMP= 950.00 K PRESSURE= .5280418E-25 MM HG LOG P= -25.277

TEMP= 975.00 K PRESSURE= .3732083E-24 MM HG LOG P= -24.428

TEMP= 1000.00 K PRESSURE= .2430000E-23 MM HG LOG P= -23.614

TEMP= 1025.00 K PRESSURE= .1464971E-22 MM HG LOG P= -22.834

TEMP= 1050.00 K PRESSURE= .8215586E-22 MM HG LOG P= -22.085

TEMP= 1075.00 K PRESSURE= .4304222E-21 MM HG LOG P= -21.366

TEMP= 1100.00 K PRESSURE= .2115013E-20 MM HG LOG P= -20.675

TEMP= 1125.00 K PRESSURE= .9783157E-20 MM HG LOG P= -20.010

TEMP= 1150.00 K PRESSURE= .4274251E-19 MM HG LOG P= -19.369

TEMP= 1175.00 K PRESSURE= .1769359E-18 MM HG LOG P= -18.752

TEMP= 1200.00 K PRESSURE= .6960000E-18 MM HG LOG P= -18.157

TEMP= 1225.00 K PRESSURE= .2608632E-17 MM HG LOG P= -17.584

TEMP= 1250.00 K PRESSURE= .9339388E-17 MM HG LOG P= -17.030

TEMP= 1275.00 K PRESSURE= .3201427E-16 MM HG LOG P= -16.495

(continued)

TABLE A-7. (Continued)

TEMP= 1300.00 K	PRESSURE= .1053022E-15 MM HG	LOG P= -15.978
TEMP= 1325.00 K	PRESSURE= .3330324E-15 MM HG	LOG P= -15.478
TEMP= 1350.00 K	PRESSURE= .1014659E-14 MM HG	LOG P= -14.994
TEMP= 1375.00 K	PRESSURE= .2983417E-14 MM HG	LOG P= -14.525
TEMP= 1400.00 K	PRESSURE= .8480000E-14 MM HG	LOG P= -14.072

MOLYBDENUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .4591283E+01 B= .2351627E+05 C= .1068924E+03

CALC FROM TEMP= 526.850 726.850 926.850 IN DEGREES C
 AND PRESSURE= .30500E-32 .24300E-23 .69600E-18 IN MM HG

TEMP= 730.00 C	PRESSURE= .3102918E-23 MM HG	LOG P= -23.508
TEMP= 735.00 C	PRESSURE= .4556731E-23 MM HG	LOG P= -23.341
TEMP= 740.00 C	PRESSURE= .6661405E-23 MM HG	LOG P= -23.176
TEMP= 745.00 C	PRESSURE= .9694882E-23 MM HG	LOG P= -23.013
TEMP= 750.00 C	PRESSURE= .1404809E-22 MM HG	LOG P= -22.852
TEMP= 755.00 C	PRESSURE= .2026857E-22 MM HG	LOG P= -22.693
TEMP= 760.00 C	PRESSURE= .2912007E-22 MM HG	LOG P= -22.536
TEMP= 765.00 C	PRESSURE= .4166361E-22 MM HG	LOG P= -22.380
TEMP= 770.00 C	PRESSURE= .5936730E-22 MM HG	LOG P= -22.226
TEMP= 775.00 C	PRESSURE= .8425464E-22 MM HG	LOG P= -22.074
TEMP= 780.00 C	PRESSURE= .1191039E-21 MM HG	LOG P= -21.924
TEMP= 785.00 C	PRESSURE= .1677153E-21 MM HG	LOG P= -21.775
TEMP= 790.00 C	PRESSURE= .2352675E-21 MM HG	LOG P= -21.628

(continued)

TABLE A-7. (Continued)

TEMP=	795.00 C	PRESSURE=	.3267921E-21 MM HG	LOG P=	-21.483
TEMP=	800.00 C	PRESSURE=	.4578023E-21 MM HG	LOG P=	-21.339
TEMP=	805.00 C	PRESSURE=	.6351235E-21 MM HG	LOG P=	-21.197
TEMP=	810.00 C	PRESSURE=	.8779862E-21 MM HG	LOG P=	-21.057
TEMP=	815.00 C	PRESSURE=	.1209461E-20 MM HG	LOG P=	-20.917
TEMP=	820.00 C	PRESSURE=	.1660332E-20 MM HG	LOG P=	-20.780
TEMP=	825.00 C	PRESSURE=	.2271547E-20 MM HG	LOG P=	-20.644
TEMP=	830.00 C	PRESSURE=	.3097387E-20 MM HG	LOG P=	-20.509
TEMP=	835.00 C	PRESSURE=	.4209586E-20 MM HG	LOG P=	-20.376
TEMP=	840.00 C	PRESSURE=	.5702643E-20 MM HG	LOG P=	-20.244
TEMP=	845.00 C	PRESSURE=	.7700659E-20 MM HG	LOG P=	-20.113
TEMP=	850.00 C	PRESSURE=	.1036612E-19 MM HG	LOG P=	-19.984

MOLYBDENUM

VAPOR PRESSURE CALCULATED FROM ANTWINE EQUATION

$$\text{LOG VP} = A - B/(C+T)$$

$$A = .1436286E+02 \quad B = .4526403E+05 \quad C = .4650222E+03$$

CALC FROM TEMP=	726.850	926.850	1126.850 IN DEGREES C
AND PRESSURE=	.24300E-23	.69600E-18	.84800E-14 IN MM HG

TEMP=	730.00 C	PRESSURE=	.3059932E-23 MM HG	LOG P=	-23.514
TEMP=	735.00 C	PRESSURE=	.4400787E-23 MM HG	LOG P=	-23.356
TEMP=	740.00 C	PRESSURE=	.6310143E-23 MM HG	LOG P=	-23.200
TEMP=	745.00 C	PRESSURE=	.9020999E-23 MM HG	LOG P=	-23.045
TEMP=	750.00 C	PRESSURE=	.1285857E-22 MM HG	LOG P=	-22.891
TEMP=	755.00 C	PRESSURE=	.1827548E-22 MM HG	LOG P=	-22.738

(continued)

TABLE A-7. (Continued)

TEMP=	760.00 C	PRESSURE=	.2589993E-22 MM HG	LOG P=	-22.587
TEMP=	765.00 C	PRESSURE=	.3660137E-22 MM HG	LOG P=	-22.437
TEMP=	770.00 C	PRESSURE=	.5157984E-22 MM HG	LOG P=	-22.288
TEMP=	775.00 C	PRESSURE=	.7248717E-22 MM HG	LOG P=	-22.140
TEMP=	780.00 C	PRESSURE=	.1015910E-21 MM HG	LOG P=	-21.993
TEMP=	785.00 C	PRESSURE=	.1419962E-21 MM HG	LOG P=	-21.848
TEMP=	790.00 C	PRESSURE=	.1979427E-21 MM HG	LOG P=	-21.703
TEMP=	795.00 C	PRESSURE=	.2752056E-21 MM HG	LOG P=	-21.560
TEMP=	800.00 C	PRESSURE=	.3816311E-21 MM HG	LOG P=	-21.418
TEMP=	805.00 C	PRESSURE=	.5278520E-21 MM HG	LOG P=	-21.277
TEMP=	810.00 C	PRESSURE=	.7282421E-21 MM HG	LOG P=	-21.138
TEMP=	815.00 C	PRESSURE=	.1002184E-20 MM HG	LOG P=	-20.999
TEMP=	820.00 C	PRESSURE=	.1375752E-20 MM HG	LOG P=	-20.861
TEMP=	825.00 C	PRESSURE=	.1883936E-20 MM HG	LOG P=	-20.725
TEMP=	830.00 C	PRESSURE=	.2573582E-20 MM HG	LOG P=	-20.589
TEMP=	835.00 C	PRESSURE=	.3507258E-20 MM HG	LOG P=	-20.455
TEMP=	840.00 C	PRESSURE=	.4768341E-20 MM HG	LOG P=	-20.322
TEMP=	845.00 C	PRESSURE=	.6467681E-20 MM HG	LOG P=	-20.189
TEMP=	850.00 C	PRESSURE=	.8752321E-20 MM HG	LOG P=	-20.058

(continued)

TABLE A-7. (Continued)

MOLYBDENUM

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

 $\text{LOG VP} = A - B/(C+T)$

A=	.4591283E+01	B=	.2351627E+05	C=	.1068924E+03
CALC FROM TEMP=	526.850	726.850	926.850	IN DEGREES C	
AND PRESSURE=	.30500E-32	.24300E-23	.69600E-18	IN MM HG	
TEMP=	781.00 C	PRESSURE=	.1275820E-21 MM HG	LOG P=	-21.894
TEMP=	782.00 C	PRESSURE=	.1366423E-21 MM HG	LOG P=	-21.864
TEMP=	783.00 C	PRESSURE=	.1463236E-21 MM HG	LOG P=	-21.835
TEMP=	784.00 C	PRESSURE=	.1566667E-21 MM HG	LOG P=	-21.805
TEMP=	785.00 C	PRESSURE=	.1677153E-21 MM HG	LOG P=	-21.775
TEMP=	786.00 C	PRESSURE=	.1795156E-21 MM HG	LOG P=	-21.746
TEMP=	787.00 C	PRESSURE=	.1921169E-21 MM HG	LOG P=	-21.716
TEMP=	788.00 C	PRESSURE=	.2055717E-21 MM HG	LOG P=	-21.687
TEMP=	789.00 C	PRESSURE=	.2199355E-21 MM HG	LOG P=	-21.658
TEMP=	790.00 C	PRESSURE=	.2352475E-21 MM HG	LOG P=	-21.628
TEMP=	791.00 C	PRESSURE=	.2516305E-21 MM HG	LOG P=	-21.599
TEMP=	792.00 C	PRESSURE=	.2690913E-21 MM HG	LOG P=	-21.570
TEMP=	793.00 C	PRESSURE=	.2877209E-21 MM HG	LOG P=	-21.541
TEMP=	794.00 C	PRESSURE=	.3075945E-21 MM HG	LOG P=	-21.512
TEMP=	795.00 C	PRESSURE=	.3287921E-21 MM HG	LOG P=	-21.483
TEMP=	796.00 C	PRESSURE=	.3513986E-21 MM HG	LOG P=	-21.454
TEMP=	797.00 C	PRESSURE=	.3755042E-21 MM HG	LOG P=	-21.425
TEMP=	798.00 C	PRESSURE=	.4012047E-21 MM HG	LOG P=	-21.397
TEMP=	799.00 C	PRESSURE=	.4286014E-21 MM HG	LOG P=	-21.368
TEMP=	800.00 C	PRESSURE=	.4578023E-21 MM HG	LOG P=	-21.339

(continued)

TABLE A-7. (Concluded)

TEMP=	801.00 C	PRESSURE=	.4889217E-21 MM HG	LOG P=	-21.311
TEMP=	802.00 C	PRESSURE=	.5220809E-21 MM HG	LOG P=	-21.282
TEMP=	803.00 C	PRESSURE=	.5574085E-21 MM HG	LOG P=	-21.254
TEMP=	804.00 C	PRESSURE=	.5950412E-21 MM HG	LOG P=	-21.225
TEMP=	805.00 C	PRESSURE=	.6351235E-21 MM HG	LOG P=	-21.197

TABLE A-8.

NICKEL

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .1102087E+02 B= .2344051E+05 C= .2733814E+02

CALC FROM TEMP= 800.000 1000.000 1200.000 IN DEGREES K
 AND PRESSURE= .488000E-17 .160000E-11 .838000E-08 IN MM HG

TEMP=	800.00 K	PRESSURE=	.4880000E-17 MM HG	LOG P=	-17.312
TEMP=	825.00 K	PRESSURE=	.3307053E-16 MM HG	LOG P=	-16.481
TEMP=	850.00 K	PRESSURE=	.2009565E-15 MM HG	LOG P=	-15.697
TEMP=	875.00 K	PRESSURE=	.1104941E-14 MM HG	LOG P=	-14.957
TEMP=	900.00 K	PRESSURE=	.5541969E-14 MM HG	LOG P=	-14.256
TEMP=	925.00 K	PRESSURE=	.2553998E-13 MM HG	LOG P=	-13.593
TEMP=	950.00 K	PRESSURE=	.1088503E-12 MM HG	LOG P=	-12.963
TEMP=	975.00 K	PRESSURE=	.4315508E-12 MM HG	LOG P=	-12.365
TEMP=	1000.00 K	PRESSURE=	.1600000E-11 MM HG	LOG P=	-11.796
TEMP=	1025.00 K	PRESSURE=	.5574024E-11 MM HG	LOG P=	-11.254
TEMP=	1050.00 K	PRESSURE=	.1832571E-10 MM HG	LOG P=	-10.737

(continued)

TABLE A-8. (Continued)

TEMP= 1075.00 K	PRESSURE= .5708309E-10 MM HG	LOG P= -10.243
TEMP= 1100.00 K	PRESSURE= .1690708E-09 MM HG	LOG P= -9.772
TEMP= 1125.00 K	PRESSURE= .4777150E-09 MM HG	LOG P= -9.321
TEMP= 1150.00 K	PRESSURE= .1291550E-08 MM HG	LOG P= -8.889
TEMP= 1175.00 K	PRESSURE= .3350359E-08 MM HG	LOG P= -8.475
TEMP= 1200.00 K	PRESSURE= .8360000E-08 MM HG	LOG P= -8.078
TEMP= 1225.00 K	PRESSURE= .2011251E-07 MM HG	LOG P= -7.697
TEMP= 1250.00 K	PRESSURE= .4675223E-07 MM HG	LOG P= -7.330
TEMP= 1275.00 K	PRESSURE= .1052141E-06 MM HG	LOG P= -6.978
TEMP= 1300.00 K	PRESSURE= .2296548E-06 MM HG	LOG P= -6.639
TEMP= 1325.00 K	PRESSURE= .4870159E-06 MM HG	LOG P= -6.312
TEMP= 1350.00 K	PRESSURE= .1004985E-05 MM HG	LOG P= -5.998
TEMP= 1375.00 K	PRESSURE= .2020962E-05 MM HG	LOG P= -5.694
TEMP= 1400.00 K	PRESSURE= .3965782E-05 MM HG	LOG P= -5.402

NICKEL

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

$$\text{LOG VP} = A - B/(C+T)$$

$$A = .1047250E+02 \quad B = .2222030E+05 \quad C = -.2159115E+01$$

CALC FROM TEMP= 1000.000 1200.000 1400.000 IN DEGREES K
AND PRESSURE= .16000E-11 .83600E-08 .37700E-05 IN MM HG

TEMP= 800.00 K	PRESSURE= .4187546E-17 MM HG	LOG P= -17.378
TEMP= 825.00 K	PRESSURE= .2938528E-16 MM HG	LOG P= -16.532
TEMP= 850.00 K	PRESSURE= .1838225E-15 MM HG	LOG P= -15.736
TEMP= 875.00 K	PRESSURE= .1035270E-14 MM HG	LOG P= -14.985

(continued)

TABLE A-8. (Continued)

TEMP=	900.00 K	PRESSURE=	.5295483E-14 MM HG	LOG P=	-14.276
TEMP=	925.00 K	PRESSURE=	.2479428E-13 MM HG	LOG P=	-13.606
TEMP=	950.00 K	PRESSURE=	.1070115E-12 MM HG	LOG P=	-12.971
TEMP=	975.00 K	PRESSURE=	.4284189E-12 MM HG	LOG P=	-12.368
TEMP=	1000.00 K	PRESSURE=	.1600000E-11 MM HG	LOG P=	-11.796
TEMP=	1025.00 K	PRESSURE=	.5602704E-11 MM HG	LOG P=	-11.252
TEMP=	1050.00 K	PRESSURE=	.1848009E-10 MM HG	LOG P=	-10.733
TEMP=	1075.00 K	PRESSURE=	.5765732E-10 MM HG	LOG P=	-10.239
TEMP=	1100.00 K	PRESSURE=	.1708045E-09 MM HG	LOG P=	-9.768
TEMP=	1125.00 K	PRESSURE=	.4821055E-09 MM HG	LOG P=	-9.317
TEMP=	1150.00 K	PRESSURE=	.1300633E-08 MM HG	LOG P=	-8.886
TEMP=	1175.00 K	PRESSURE=	.3363509E-08 MM HG	LOG P=	-8.473
TEMP=	1200.00 K	PRESSURE=	.8360000E-08 MM HG	LOG P=	-8.078
TEMP=	1225.00 K	PRESSURE=	.2001945E-07 MM HG	LOG P=	-7.699
TEMP=	1250.00 K	PRESSURE=	.4629157E-07 MM HG	LOG P=	-7.334
TEMP=	1275.00 K	PRESSURE=	.1035740E-06 MM HG	LOG P=	-6.985
TEMP=	1300.00 K	PRESSURE=	.2246600E-06 MM HG	LOG P=	-6.648
TEMP=	1325.00 K	PRESSURE=	.4732496E-06 MM HG	LOG P=	-6.325
TEMP=	1350.00 K	PRESSURE=	.9697318E-06 MM HG	LOG P=	-6.013
TEMP=	1375.00 K	PRESSURE=	.1935823E-05 MM HG	LOG P=	-5.713
TEMP=	1400.00 K	PRESSURE=	.3770000E-05 MM HG	LOG P=	-5.424

(continued)

TABLE A-8. (Continued)

NICKEL

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .1102087E+02 B= .2344051E+05 C= .3004881E+03

CALC FROM TEMP= 526.850 726.850 926.850 IN DEGREES C
 AND PRESSURE= .48800E-17 .16000E-11 .83600E-08 IN MM HG

TEMP= 730.00 C PRESSURE= .1878738E-11 MM HG LOG P= -11.726

TEMP= 735.00 C PRESSURE= .2419376E-11 MM HG LOG P= -11.616

TEMP= 740.00 C PRESSURE= .3108027E-11 MM HG LOG P= -11.508

TEMP= 745.00 C PRESSURE= .3983142E-11 MM HG LOG P= -11.400

TEMP= 750.00 C PRESSURE= .5092618E-11 MM HG LOG P= -11.293

TEMP= 755.00 C PRESSURE= .6495991E-11 MM HG LOG P= -11.187

TEMP= 760.00 C PRESSURE= .8267096E-11 MM HG LOG P= -11.083

TEMP= 765.00 C PRESSURE= .1049730E-10 MM HG LOG P= -10.979

TEMP= 770.00 C PRESSURE= .1329945E-10 MM HG LOG P= -10.876

TEMP= 775.00 C PRESSURE= .1681257E-10 MM HG LOG P= -10.774

TEMP= 780.00 C PRESSURE= .2120764E-10 MM HG LOG P= -10.674

TEMP= 785.00 C PRESSURE= .2669448E-10 MM HG LOG P= -10.574

TEMP= 790.00 C PRESSURE= .3353005E-10 MM HG LOG P= -10.475

TEMP= 795.00 C PRESSURE= .4202843E-10 MM HG LOG P= -10.376

TEMP= 800.00 C PRESSURE= .5257273E-10 MM HG LOG P= -10.279

TEMP= 805.00 C PRESSURE= .6562942E-10 MM HG LOG P= -10.183

TEMP= 810.00 C PRESSURE= .8176530E-10 MM HG LOG P= -10.087

TEMP= 815.00 C PRESSURE= .1016678E-09 MM HG LOG P= -9.993

TEMP= 820.00 C PRESSURE= .1261693E-09 MM HG LOG P= -9.899

TEMP= 825.00 C PRESSURE= .1562755E-09 MM HG LOG P= -9.806

(continued)

TABLE A-8. (Continued)

TEMP=	830.00 C	PRESSURE=	.1931994E-09 MM HG	LOG P=	-9.714
TEMP=	835.00 C	PRESSURE=	.2384018E-09 MM HG	LOG P=	-9.623
TEMP=	840.00 C	PRESSURE=	.2936383E-09 MM HG	LOG P=	-9.532
TEMP=	845.00 C	PRESSURE=	.3610155E-09 MM HG	LOG P=	-9.442
TEMP=	850.00 C	PRESSURE=	.4430565E-09 MM HG	LOG P=	-9.354

NICKEL

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

$$\text{LOG VP} = A - B/(C+T)$$

A= .1047250E+02 B= .2222030E+05 C= .2709909E+03

CALC FROM TEMP= 726.850 926.850 1126.850 IN DEGREES C
AND PRESSURE= .16000E-11 .83600E-08 .37700E-05 IN MM HG

TEMP=	730.00 C	PRESSURE=	.1880165E-11 MM HG	LOG P=	-11.726
TEMP=	735.00 C	PRESSURE=	.2423966E-11 MM HG	LOG P=	-11.615
TEMP=	740.00 C	PRESSURE=	.3117207E-11 MM HG	LOG P=	-11.506
TEMP=	745.00 C	PRESSURE=	.3998800E-11 MM HG	LOG P=	-11.398
TEMP=	750.00 C	PRESSURE=	.5117223E-11 MM HG	LOG P=	-11.291
TEMP=	755.00 C	PRESSURE=	.6532735E-11 MM HG	LOG P=	-11.185
TEMP=	760.00 C	PRESSURE=	.8320071E-11 MM HG	LOG P=	-11.080
TEMP=	765.00 C	PRESSURE=	.1057171E-10 MM HG	LOG P=	-10.976
TEMP=	770.00 C	PRESSURE=	.1340183E-10 MM HG	LOG P=	-10.873
TEMP=	775.00 C	PRESSURE=	.1695111E-10 MM HG	LOG P=	-10.771
TEMP=	780.00 C	PRESSURE=	.2139249E-10 MM HG	LOG P=	-10.670
TEMP=	785.00 C	PRESSURE=	.2693814E-10 MM HG	LOG P=	-10.570
TEMP=	790.00 C	PRESSURE=	.3384778E-10 MM HG	LOG P=	-10.470

(continued)

TABLE A-8. (Continued)

TEMP=	795.00 C	PRESSURE=	.4243875E-10 MM HG	LOG P=	-10.372
TEMP=	800.00 C	PRESSURE=	.5309795E-10 MM HG	LOG P=	-10.275
TEMP=	805.00 C	PRESSURE=	.6629618E-10 MM HG	LOG P=	-10.179
TEMP=	810.00 C	PRESSURE=	.8260521E-10 MM HG	LOG P=	-10.083
TEMP=	815.00 C	PRESSURE=	.1027180E-09 MM HG	LOG P=	-9.988
TEMP=	820.00 C	PRESSURE=	.1274731E-09 MM HG	LOG P=	-9.895
TEMP=	825.00 C	PRESSURE=	.1578828E-09 MM HG	LOG P=	-9.802
TEMP=	830.00 C	PRESSURE=	.1951674E-09 MM HG	LOG P=	-9.710
TEMP=	835.00 C	PRESSURE=	.2407948E-09 MM HG	LOG P=	-9.618
TEMP=	840.00 C	PRESSURE=	.2965280E-09 MM HG	LOG P=	-9.528
TEMP=	845.00 C	PRESSURE=	.3644804E-09 MM HG	LOG P=	-9.438
TEMP=	850.00 G	PRESSURE=	.4471808E-09 MM HG	LOG P=	-9.350

NICKEL

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .1102087E+02 B= .2344051E+05 C= .3004881E+03

CALC FROM TEMP= 526.850 726.850 926.850 IN DEGREES C
 AND PRESSURE= .48800E-17 .16000E-11 .83600E-08 IN MM HG

TEMP=	781.00 C	PRESSURE=	.2221018E-10 MM HG	LOG P=	-10.653
TEMP=	782.00 C	PRESSURE=	.2325913E-10 MM HG	LOG P=	-10.633
TEMP=	783.00 C	PRESSURE=	.2435345E-10 MM HG	LOG P=	-10.613
TEMP=	784.00 C	PRESSURE=	.2549819E-10 MM HG	LOG P=	-10.593
TEMP=	785.00 C	PRESSURE=	.2669448E-10 MM HG	LOG P=	-10.574

(continued)

TABLE A-8. (Concluded)

TEMP=	786.00 C	PRESSURE=	.2794454E-10 MM HG	LOG P=	-10.554
TEMP=	787.00 C	PRESSURE=	.2925067E-10 MM HG	LOG P=	-10.534
TEMP=	788.00 C	PRESSURE=	.3061528E-10 MM HG	LOG P=	-10.514
TEMP=	789.00 C	PRESSURE=	.3204087E-10 MM HG	LOG P=	-10.494
TEMP=	790.00 C	PRESSURE=	.3353005E-10 MM HG	LOG P=	-10.475
TEMP=	791.00 C	PRESSURE=	.3508552E-10 MM HG	LOG P=	-10.455
TEMP=	792.00 C	PRESSURE=	.3671010E-10 MM HG	LOG P=	-10.435
TEMP=	793.00 C	PRESSURE=	.3840672E-10 MM HG	LOG P=	-10.416
TEMP=	794.00 C	PRESSURE=	.4017844E-10 MM HG	LOG P=	-10.396
TEMP=	795.00 C	PRESSURE=	.4202843E-10 MM HG	LOG P=	-10.376
TEMP=	796.00 C	PRESSURE=	.4395998E-10 MM HG	LOG P=	-10.357
TEMP=	797.00 C	PRESSURE=	.4597655E-10 MM HG	LOG P=	-10.337
TEMP=	798.00 C	PRESSURE=	.4808169E-10 MM HG	LOG P=	-10.318
TEMP=	799.00 C	PRESSURE=	.5027913E-10 MM HG	LOG P=	-10.299
TEMP=	800.00 C	PRESSURE=	.5257273E-10 MM HG	LOG P=	-10.279
TEMP=	801.00 C	PRESSURE=	.5496650E-10 MM HG	LOG P=	-10.260
TEMP=	802.00 C	PRESSURE=	.5746463E-10 MM HG	LOG P=	-10.241
TEMP=	803.00 C	PRESSURE=	.6007145E-10 MM HG	LOG P=	-10.221
TEMP=	804.00 C	PRESSURE=	.6279148E-10 MM HG	LOG P=	-10.202
TEMP=	805.00 C	PRESSURE=	.6562942E-10 MM HG	LOG P=	-10.183

TABLE A-9.

ZINC

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

$$\text{LOG VP} = A - B/(C+T)$$

A= .7861609E+01 B= .5702700E+04 C= -.3488297E+02

CALC FROM TEMP= 800.000 1000.000 1200.000 IN DEGREES K
AND PRESSURE= .25600E+01 .89700E+02 .92700E+03 IN MM HG

TEMP= 800.00 K	PRESSURE= .2560000E+01 MM HG	LOG P= .408
TEMP= 825.00 K	PRESSURE= .4406270E+01 MM HG	LOG P= .644
TEMP= 850.00 K	PRESSURE= .7335610E+01 MM HG	LOG P= .865
TEMP= 875.00 K	PRESSURE= .1184750E+02 MM HG	LOG P= 1.074
TEMP= 900.00 K	PRESSURE= .1861164E+02 MM HG	LOG P= 1.270
TEMP= 925.00 K	PRESSURE= .2850519E+02 MM HG	LOG P= 1.455
TEMP= 950.00 K	PRESSURE= .4265280E+02 MM HG	LOG P= 1.630
TEMP= 975.00 K	PRESSURE= .6246872E+02 MM HG	LOG P= 1.796
TEMP= 1000.00 K	PRESSURE= .8970000E+02 MM HG	LOG P= 1.953
TEMP= 1025.00 K	PRESSURE= .1264700E+03 MM HG	LOG P= 2.102
TEMP= 1050.00 K	PRESSURE= .1753209E+03 MM HG	LOG P= 2.244
TEMP= 1075.00 K	PRESSURE= .2392550E+03 MM HG	LOG P= 2.379
TEMP= 1100.00 K	PRESSURE= .3217733E+03 MM HG	LOG P= 2.508
TEMP= 1125.00 K	PRESSURE= .4269100E+03 MM HG	LOG P= 2.630
TEMP= 1150.00 K	PRESSURE= .5592643E+03 MM HG	LOG P= 2.748
TEMP= 1175.00 K	PRESSURE= .7240267E+03 MM HG	LOG P= 2.860
TEMP= 1200.00 K	PRESSURE= .9270000E+03 MM HG	LOG P= 2.967
TEMP= 1225.00 K	PRESSURE= .1174616E+04 MM HG	LOG P= 3.070
TEMP= 1250.00 K	PRESSURE= .1473945E+04 MM HG	LOG P= 3.168
TEMP= 1275.00 K	PRESSURE= .1832702E+04 MM HG	LOG P= 3.263

(continued)

TABLE A-9. (Continued)

TEMP= 1300.00 K	PRESSURE= .2259245E+04 MM HG	LOG P= 3.354
TEMP= 1325.00 K	PRESSURE= .2762567E+04 MM HG	LOG P= 3.441
TEMP= 1350.00 K	PRESSURE= .3352289E+04 MM HG	LOG P= 3.525
TEMP= 1375.00 K	PRESSURE= .4038638E+04 MM HG	LOG P= 3.606
TEMP= 1400.00 K	PRESSURE= .4832429E+04 MM HG	LOG P= 3.684

ZINC

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION
 $\text{LOG VP} = A - B/(C+T)$

A= .7651451E+01	B= .5263722E+04	C= -.7632259E+02
CALC FROM TEMP= 1000.000	1200.000	1400.000 IN DEGREES K
AND PRESSURE= .89700E+02	.92700E+03	.47300E+04 IN MM HG

TEMP= 800.00 K	PRESSURE= .2387128E+01 MM HG	LOG P= .378
TEMP= 825.00 K	PRESSURE= .4175961E+01 MM HG	LOG P= .621
TEMP= 850.00 K	PRESSURE= .7045970E+01 MM HG	LOG P= .848
TEMP= 875.00 K	PRESSURE= .1150542E+02 MM HG	LOG P= 1.061
TEMP= 900.00 K	PRESSURE= .1823630E+02 MM HG	LOG P= 1.261
TEMP= 925.00 K	PRESSURE= .2813106E+02 MM HG	LOG P= 1.449
TEMP= 950.00 K	PRESSURE= .4233132E+02 MM HG	LOG P= 1.627
TEMP= 975.00 K	PRESSURE= .6226778E+02 MM HG	LOG P= 1.794
TEMP= 1000.00 K	PRESSURE= .8970000E+02 MM HG	LOG P= 1.953
TEMP= 1025.00 K	PRESSURE= .1267553E+03 MM HG	LOG P= 2.103
TEMP= 1050.00 K	PRESSURE= .1759658E+03 MM HG	LOG P= 2.245
TEMP= 1075.00 K	PRESSURE= .2403023E+03 MM HG	LOG P= 2.381
TEMP= 1100.00 K	PRESSURE= .3232045E+03 MM HG	LOG P= 2.509

(continued)

TABLE A-9. (Continued)

TEMP= 1125.00 K	PRESSURE= .4286075E+03 MM HG	LOG P= 2.632
TEMP= 1150.00 K	PRESSURE= .5609622E+03 MM HG	LOG P= 2.749
TEMP= 1175.00 K	PRESSURE= .7252514E+03 MM HG	LOG P= 2.860
TEMP= 1200.00 K	PRESSURE= .9270000E+03 MM HG	LOG P= 2.967
TEMP= 1225.00 K	PRESSURE= .1172279E+04 MM HG	LOG P= 3.069
TEMP= 1250.00 K	PRESSURE= .1467707E+04 MM HG	LOG P= 3.167
TEMP= 1275.00 K	PRESSURE= .1820438E+04 MM HG	LOG P= 3.260
TEMP= 1300.00 K	PRESSURE= .2238158E+04 MM HG	LOG P= 3.350
TEMP= 1325.00 K	PRESSURE= .2729060E+04 MM HG	LOG P= 3.436
TEMP= 1350.00 K	PRESSURE= .3301828E+04 MM HG	LOG P= 3.519
TEMP= 1375.00 K	PRESSURE= .3965613E+04 MM HG	LOG P= 3.598
TEMP= 1400.00 K	PRESSURE= .4730000E+04 MM HG	LOG P= 3.675

ZINC

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .7861609E+01 B= .5702700E+04 C= .2382670E+03

CALC FROM TEMP= 526.850 726.850 926.850 IN DEGREES C
 AND PRESSURE= .25600E+01 .89700E+02 .92700E+03 IN MM HG

TEMP= 730.00 C	PRESSURE= .9375948E+02 MM HG	LOG P= 1.972
TEMP= 735.00 C	PRESSURE= .1005245E+03 MM HG	LOG P= 2.002
TEMP= 740.00 C	PRESSURE= .1077010E+03 MM HG	LOG P= 2.032
TEMP= 745.00 C	PRESSURE= .1153088E+03 MM HG	LOG P= 2.062
TEMP= 750.00 C	PRESSURE= .1233689E+03 MM HG	LOG P= 2.091
TEMP= 755.00 C	PRESSURE= .1319025E+03 MM HG	LOG P= 2.120

(continued)

TABLE A-9. (Continued)

TEMP=	760.00 C	PRESSURE=	.1409320E+03 MM HG	LOG P=	2.149
TEMP=	765.00 C	PRESSURE=	.1504803E+03 MM HG	LOG P=	2.177
TEMP=	770.00 C	PRESSURE=	.1605711E+03 MM HG	LOG P=	2.206
TEMP=	775.00 C	PRESSURE=	.1712288E+03 MM HG	LOG P=	2.234
TEMP=	780.00 C	PRESSURE=	.1824787E+03 MM HG	LOG P=	2.261
TEMP=	785.00 C	PRESSURE=	.1943468E+03 MM HG	LOG P=	2.289
TEMP=	790.00 C	PRESSURE=	.2068600E+03 MM HG	LOG P=	2.316
TEMP=	795.00 C	PRESSURE=	.2200460E+03 MM HG	LOG P=	2.343
TEMP=	800.00 C	PRESSURE=	.2339332E+03 MM HG	LOG P=	2.369
TEMP=	805.00 C	PRESSURE=	.2485510E+03 MM HG	LOG P=	2.395
TEMP=	810.00 C	PRESSURE=	.2639296E+03 MM HG	LOG P=	2.421
TEMP=	815.00 C	PRESSURE=	.2800999E+03 MM HG	LOG P=	2.447
TEMP=	820.00 C	PRESSURE=	.2970941E+03 MM HG	LOG P=	2.473
TEMP=	825.00 C	PRESSURE=	.3149447E+03 MM HG	LOG P=	2.498
TEMP=	830.00 C	PRESSURE=	.3336856E+03 MM HG	LOG P=	2.523
TEMP=	835.00 C	PRESSURE=	.3533514E+03 MM HG	LOG P=	2.548
TEMP=	840.00 C	PRESSURE=	.3739774E+03 MM HG	LOG P=	2.573
TEMP=	845.00 C	PRESSURE=	.3956002E+03 MM HG	LOG P=	2.597
TEMP=	850.00 C	PRESSURE=	.4182572E+03 MM HG	LOG P=	2.621

(continued)

TABLE A-9. (Continued)

ZINC

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .7651451E+01 B= .5263722E+04 C= .1968274E+03

CALC FROM TEMP= 726.850 926.850 1126.850 IN DEGREES C
 AND PRESSURE= .89700E+02 .92700E+03 .47300E+04 IN MM HG

TEMP= 730.00 C PRESSURE= .9379084E+02 MM HG LOG P= 1.972

TEMP= 735.00 C PRESSURE= .1006084E+03 MM HG LOG P= 2.003

TEMP= 740.00 C PRESSURE= .1078408E+03 MM HG LOG P= 2.033

TEMP= 745.00 C PRESSURE= .1155079E+03 MM HG LOG P= 2.063

TEMP= 750.00 C PRESSURE= .1236303E+03 MM HG LOG P= 2.092

TEMP= 755.00 C PRESSURE= .1322295E+03 MM HG LOG P= 2.121

TEMP= 760.00 C PRESSURE= .1413275E+03 MM HG LOG P= 2.150

TEMP= 765.00 C PRESSURE= .1509470E+03 MM HG LOG P= 2.179

TEMP= 770.00 C PRESSURE= .1611115E+03 MM HG LOG P= 2.207

TEMP= 775.00 C PRESSURE= .1718451E+03 MM HG LOG P= 2.235

TEMP= 780.00 C PRESSURE= .1831729E+03 MM HG LOG P= 2.263

TEMP= 785.00 C PRESSURE= .1951205E+03 MM HG LOG P= 2.290

TEMP= 790.00 C PRESSURE= .2077143E+03 MM HG LOG P= 2.317

TEMP= 795.00 C PRESSURE= .2209816E+03 MM HG LOG P= 2.344

TEMP= 800.00 C PRESSURE= .2349503E+03 MM HG LOG P= 2.371

TEMP= 805.00 C PRESSURE= .2496492E+03 MM HG LOG P= 2.397

TEMP= 810.00 C PRESSURE= .2651079E+03 MM HG LOG P= 2.423

TEMP= 815.00 C PRESSURE= .2813567E+03 MM HG LOG P= 2.449

TEMP= 820.00 C PRESSURE= .2984268E+03 MM HG LOG P= 2.475

TEMP= 825.00 C PRESSURE= .3163501E+03 MM HG LOG P= 2.500

(continued)

TABLE A-9. (Continued)

TEMP=	830.00 C	PRESSURE=	.3351595E+03 MM HG	LOG P=	2.525
TEMP=	835.00 C	PRESSURE=	.3548885E+03 MM HG	LOG P=	2.550
TEMP=	840.00 C	PRESSURE=	.3755715E+03 MM HG	LOG P=	2.575
TEMP=	845.00 C	PRESSURE=	.3972440E+03 MM HG	LOG P=	2.599
TEMP=	850.00 C	PRESSURE=	.4199420E+03 MM HG	LOG P=	2.623

ZINC

VAPOR PRESSURE CALCULATED FROM ANTOINE EQUATION

LOG VP = A - B/(C+T)

A= .7861609E+01 B= .5702700E+04 C= .2382670E+03

CALC FROM TEMP= 526.850 726.850 926.850 IN DEGREES C
 AND PRESSURE= .25600E+01 .89700E+02 .92700E+03 IN MM HG

TEMP=	781.00 C	PRESSURE=	.1848020E+03 MM HG	LOG P=	2.267
TEMP=	782.00 C	PRESSURE=	.1871503E+03 MM HG	LOG P=	2.272
TEMP=	783.00 C	PRESSURE=	.1895237E+03 MM HG	LOG P=	2.278
TEMP=	784.00 C	PRESSURE=	.1919225E+03 MM HG	LOG P=	2.283
TEMP=	785.00 C	PRESSURE=	.1943468E+03 MM HG	LOG P=	2.289
TEMP=	786.00 C	PRESSURE=	.1967970E+03 MM HG	LOG P=	2.294
TEMP=	787.00 C	PRESSURE=	.1992732E+03 MM HG	LOG P=	2.299
TEMP=	788.00 C	PRESSURE=	.2017756E+03 MM HG	LOG P=	2.305
TEMP=	789.00 C	PRESSURE=	.2043045E+03 MM HG	LOG P=	2.310
TEMP=	790.00 C	PRESSURE=	.2068600E+03 MM HG	LOG P=	2.316
TEMP=	791.00 C	PRESSURE=	.2094425E+03 MM HG	LOG P=	2.321
TEMP=	792.00 C	PRESSURE=	.2120521E+03 MM HG	LOG P=	2.326
TEMP=	793.00 C	PRESSURE=	.2146891E+03 MM HG	LOG P=	2.332

(continued)

TABLE A-9. (Concluded)

TEMP=	794.00 C	PRESSURE=	.2173536E+03 MM HG	LOG P=	2.337
TEMP=	795.00 C	PRESSURE=	.2200460E+03 MM HG	LOG P=	2.343
TEMP=	796.00 C	PRESSURE=	.2227664E+03 MM HG	LOG P=	2.348
TEMP=	797.00 C	PRESSURE=	.2255151E+03 MM HG	LOG P=	2.353
TEMP=	798.00 C	PRESSURE=	.2282923E+03 MM HG	LOG P=	2.358
TEMP=	799.00 C	PRESSURE=	.2310983E+03 MM HG	LOG P=	2.364
TEMP=	800.00 C	PRESSURE=	.2339332E+03 MM HG	LOG P=	2.369
TEMP=	801.00 C	PRESSURE=	.2367974E+03 MM HG	LOG P=	2.374
TEMP=	802.00 C	PRESSURE=	.2396910E+03 MM HG	LOG P=	2.380
TEMP=	803.00 C	PRESSURE=	.2426143E+03 MM HG	LOG P=	2.385
TEMP=	804.00 C	PRESSURE=	.2455676E+03 MM HG	LOG P=	2.390
TEMP=	805.00 C	PRESSURE=	.2485510E+03 MM HG	LOG P=	2.395

FIGURE A-1. Vapor Pressures of Pure Components

FIGURE A-2. Zinc Vapor Pressures From Two Sets of Antoine Equation Constants

APPENDIX B

PHASE DIAGRAMS

Several phase diagrams that are applicable to the zinc-cladding mixture are as follows:

<u>Binary Systems</u>	<u>References</u>
Chromium-Iron	1
Chromium-Nickel	1
Chromium-Zinc	11
Iron-Magnesium	11
Iron-Nickel	1
Magnesium-Nickel	1
Magnesium-Zinc	1
Nickel-Zinc	1
 <u>Ternary Systems</u>	
Chromium-Iron-Molybdenum	1
Chromium-Iron-Nickel	1
Chromium-Molybdenum-Nickel	1
Iron-Molybdenum-Nickel	1