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THERMAL CONDUCTIVITY OF URANIUM-PLUTONIUM OXIDE

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ITEM	REFERENCES (SECTION, PAGE, PARAGRAPH, LINE)	INSTRUCTIONS (CORRECTIONS AND ADDITIONS)
1.	Section 7; Page 24; first line of equation...	<p>Change: $\frac{360.2}{(2.04 - O/M)T^3}$ to $\frac{360.2}{(2.04 - O/M)T^2}$</p>
2.	Table A-1, Page 29; Column 7 with heading reading Test Number	<p>(a) Add an asterisk next to the word Number, i.e., Number*</p> <p>(b) For footnote explaining asterisk, add following sketch at bottom of Table:</p> <div data-bbox="648 1105 1402 1371"> <p>*8. 2 0 7</p> <p>Run Number in Test</p> <p>Pellet Number, 1 = Top, 2 = Middle, 3 = Bottom</p> <p>Test Number (See Table 1, page 10)</p> </div>

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THERMAL CONDUCTIVITY OF URANIUM - PLUTONIUM OXIDE

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ABSTRACT

Out-of-pile thermal conductivity measurements were made on urania-plutonia fuel mixtures for varying fuel temperature, density, stoichiometry, composition and fabrication method. The measurements were made in a helium-6% hydrogen atmosphere using a radial heat flow technique. The empirical equation developed for the thermal conductivity of $(U_{0.8}Pu_{0.2})O_{2-x}$ is:

$$k = 0.01524 + \frac{1}{(0.9702 - 0.4465D)T} + 0.5841 \times 10^{-12} T^3 + \frac{360.2}{(2.04 - O/M)T^2}$$

where

k = thermal conductivity (watts/cm-°C)

T = temperature (800-2300°C)

D = fractional density (0.84 - 0.91)

O/M = stoichiometry (1.94 - 2.00)

Typical values for k on this curve (for D = 0.91, Pu/(U+Pu) = 0.2 and O/M = 2.00) are:

T (°C)	k (W/cm-°C)
800	0.0318
1000	0.0266
1500	0.0224
2000	0.0231
2300	0.0248

The equation was obtained using a weighted non-linear regression analysis. Data above ~1800°C indicated that the thermal conductivity increased slightly above this temperature. The results are in good agreement with previously published data. Error analyses inherent in the regression technique used showed that the equation has 90% confidence limits of ± 11% which reflect the experimental and curve fitting errors involved in its development.

1. SUMMARY

Out-of-pile thermal conductivity measurements were made on urania-plutonia fuel mixtures as a function of fuel temperature, density, stoichiometry, composition and fabrication method. An empirical equation was developed for the thermal conductivity of UO_2 -20% PuO_2 .

Using weighted, non-linear regression analyses, an empirical equation for the thermal conductivity of $(U_{0.8}Pu_{0.2})O_{2-x}$ was determined as a function of several variables. The equation is:

$$k = 0.01524 + \frac{1}{(0.9702 - 0.4465D)T} + 0.5841 \times 10^{-12} T^3 + \frac{360.2}{(2.04 - O/M)T^2}$$

where

k = thermal conductivity (watts/cm-°C)

T = temperature (800 to 2300°C)

D = fractional density (0.84 to 0.91)

O/M = oxygen/metal ratio (1.94 to 2.00)

Statistical analyses showed that this empirical equation had 90% confidence limits of ± 11%. Measurements showed that the thermal conductivity increased slightly at temperatures greater than about 1800°C. This result was included in the empirical equation and is largely accounted for by the T^3 term of the equation.

The effect of density change on the thermal conductivity of mixed oxide fuel was found to be much less than in previous studies using stoichiometric uranium dioxide. The effects of varying density and plutonium composition were overshadowed by the effects of varying stoichiometry. The thermal conductivity was found to increase as the stoichiometry increased.

Fuel fabrication methods were found to have a negligible effect on the thermal conductivity. It was presumed, but not investigated here, that this would indeed be the case as long as the plutonia in the mixed oxide fuel remained well-distributed throughout the fuel lattice.

The application of the out-of-pile thermal conductivity data from this experiment to in-pile usage requires additional input from integral to melt thermal conductivity data to ensure that the required boundary conditions are fully met.

2. INTRODUCTION

One important parameter in determining the limiting power level for an oxide nuclear fuel element is the thermal conductivity of the fuel. In addition, the shape of the conductivity versus temperature curve is of importance in calculating the Doppler coefficient and transient behavior of fast flux, oxide-fueled reactors. Although several in-pile and out-of-pile investigations of thermal conductivity of stoichiometric and hyperstoichiometric uranium dioxide have been reported, relatively little work has been done with mixed uranium-plutonium oxide fuels.

In-pile conductivity data are complicated by the compound effect of fission product generation, fuel restructuring, and power cycling, as well as time and temperature. Some of these variables can be interpreted by out-of-pile measurements which provide the basis for a systematic evaluation of any existing trends.

The use of plutonium-uranium oxides as fast ceramic reactor fuels requires a thorough understanding of the thermal behavior of the material. Due to the large temperature gradients that occur in the fuel during irradiation, a variety of structures and compositions develops in the fuel matrix which affect both the physical and mechanical properties. Preferential migration of oxygen to the colder regions of the mixed oxide fuel has been observed out-of-pile. In a similar manner the plutonium in mixed oxide fuels irradiated in a fast flux tend to migrate to the center of the fuel. The occurrence of equiaxed and columnar grain growth also result in a variety of density and grain size regions. All of the above conditions produce a complex fuel matrix which can appreciably alter the heat transfer across the fuel pin.

The thermal conductivity data now available in the literature is not adequate to cover the various conditions and temperature ranges of concern found in irradiated fuel. Much of the current data available is in the form of thermal diffusivity measurements which require somewhat uncertain heat capacity data for conversion to actual thermal conductivity (watts/cm²°C) measurements.

The out-of-pile thermal conductivity study reported here was designed to yield data which will be directly applicable to realistic conditions.

This work was undertaken to obtain an equation for the thermal conductivity of 20% plutonium concentration (Pu-U)O₂ as a function of temperatures, fuel densities and composition which will be encountered in fast ceramic reactor fuels. Other fuel parameters such as oxygen/metal (O/M) ratio and fuel powder preparation methods were also studied to investigate their effects on thermal conductivity. The thermal conductivity of stoichiometric UO₂ was also measured.

It is the purpose of this report to present these experimental results in graphical and tabular form, as well as obtaining a mathematical expression for the thermal conductivity of mixed oxide fuel based on out-of-pile measurements.

3. PRIOR WORK

The thermal conductivity characteristics of uranium dioxide have been extensively investigated both in- and out-of-pile, and the results summarized by Asamoto.¹ However, relatively few investigations have studied the (Pu-U)O₂ system. Some of the early work has been summarized by Hetzler,² and more recent contributions have been made by him along with Schmidt,³ Gibby,⁴ Van Craeynest⁵ and Baily.⁶ While these experimenters used three different experimental techniques to measure the thermal conductivity of mixed oxide fuel, their results are in reasonable agreement. As an example of comparison, the curves of thermal conductivity versus temperature for these recent experiments (for 96% T.D. and O/M = 2.00) are plotted in Figure 1 along with the results of the measurements reported here for the same experimental conditions.

Figure 1. Comparison of Mixed Oxide Thermal Conductivity Data Versus Temperature for Several Experimenters

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Additional thermal conductivity values were needed to supplement the information already available on mixed plutonium-uranium oxide fuels because of the following conditions:

- 1) A large portion of the data was developed from thermal diffusivity measurements. Since thermal conductivity values are calculated using estimated numbers for the specific heat of the material, there is some uncertainty in the conductivity values obtained.
- 2) Little data have been reported for temperatures greater than 1900°C.
- 3) The data on the effects of plutonium content and density are sparse and inconclusive.
- 4) While the role of stoichiometry in the thermal conductivity has been investigated by several authors,^{2,3,7} inadequate control of the test atmospheres may well have resulted in O/M shifts during high temperature tests. In general these possible stoichiometry changes were not taken into account in the analysis of the earlier data.

The present out-of-pile thermal conductivity study fills in the areas where data are needed and also serves as a check on the data already present in the literature.

It is worthwhile to note that Baily⁶ retained the same density correlation factor that was developed by Asamoto¹ for UO_2 ; however, the thermal conductivity was presumed to be constant above 2000°C. Also, all data at high temperatures ($> 2000^\circ\text{C}$) is subject to some speculation. The high temperature electrical conductivity of the fuel may be sufficiently large enough at high temperatures so that some joule heating occurs in the specimen itself rather than being confined to a tungsten rod which is used as a heat source by several experimenters. Ainscough⁸ has shown that such power generation in the specimens will lead to artificially high values for the measured thermal conductivity. Gibby⁴ has eliminated this problem using his laser pulse technique; however, his results using the calculation of thermal diffusivity required knowing the fuel heat capacity (C_p) accurately. Calculations of this latter quantity are subject to error. Gibby's studies used 95.5% dense, 25% PuO_2 coprecipitated fuel.

Schmidt⁹, in a recent paper, asserts that the mechanisms of electronic and radiative heat transfer have only minor effects, if any, on the thermal conductivity of uranium dioxide. His analysis demonstrated that the specific heat of the fuel material was the predominant factor in determining the temperature dependence of the thermal conductivity of UO_2 above 1200°C. He also determined that 2050°C is the limiting temperature above which the thermal conductivity of UO_2 begins to increase because the specific heat increases with temperature in this region. Several authors^{10,11,12} have shown this trend of specific heat versus temperature for UO_2 , PuO_2 and mixed oxide fuels.

4. EXPERIMENTAL DESIGN

4.1 TEST FURNACE

Thermal conductivity measurements were carried out in a vacuum furnace modified to accommodate a radial heat flow power generation apparatus.

A schematic diagram of the furnace used for these experiments is shown in Figure 2. Several modifications were made to the standard frame in order to provide a viable experimental arrangement in an alpha enclosure. Electrodes were fitted through the top and bottom of the furnace casing so that the annular test pellets could be placed on a tungsten rod heated by means of the electrodes. Electrical contact between the tungsten rod and the bottom electrode was provided through a Ga-24.5% In eutectic liquid metal pool. This eliminated any tungsten rod expansion problems. Legs were fastened to the bottom of the furnace to provide clearance and access under the furnace case. The furnace door was modified so that it could be swung to the side of the furnace, providing improved access to the furnace interior through the alpha enclosure glove ports. Figures 3 through 5 show the furnace and its instrumentation.

General furnace heating was provided by tungsten mesh elements in the furnace case and on the furnace door. The purpose of the tungsten mesh heaters was to control the outer surface temperature of the test specimens so that the ΔT could be adjusted to desired values. Large interlocking copper blades completed the electrical circuits when the door was closed.

Separate SCR linear power control supplies provided power to the tungsten mesh and rod heaters. The two heat sources could be controlled separately but operated simultaneously if desired.

The furnace door was supplied with a 2-inch by 1/4-inch slit (covered by a vycor window) for viewing the pellet column with minimum heat loss from the furnace.

71-1

Figure 2. Schematic of Thermal Conductivity Apparatus

NEGATIVE No. A 681233

71-2

Figure 3. Vacuum Furnace—Closed

NEGATIVE No. A 681234

71-3

Figure 4. Vacuum Furnace—Open

NEGATIVE No. A 681237
71-4

Figure 5. Vacuum Furnace Instrumentation

4.2 SPECIMEN PREPARATION

Test pellets were fabricated to various stoichiometry, plutonium content, and density specifications. The majority of the pellets were prepared from physically mixed PuO_2 and UO_2 but a few were prepared from coprecipitated powder. Physically mixed UO_2 -20% PuO_2 was prepared by blending the proper amounts of UO_2 and PuO_2 powders in a twin shell blender followed by hammermilling. UO_2 -10% was prepared from UO_2 -20% PuO_2 by blending in additional UO_2 . Coprecipitated UO_2 -20% PuO_2 and UO_2 -30% PuO_2 were prepared by precipitating the proper mixtures of uranyl nitrate and plutonium nitrate using the reverse strike method. The precipitates were washed and then calcined at 700°C in dry N_2 -6% H_2 followed by ball-milling to obtain a sinterable powder.

Fabrication procedures and quality control checks were used to promote a single-phase solid solution and protect against large inhomogeneities in the fuel matrix.

The experimental arrangement is illustrated in Figure 6. The stack of three pellets in each test usually contained two mixed oxide pellets and one uranium oxide pellet. Each pellet contained four black-body holes, and beginning with Test 8 (see Table 1), the UO_2 pellet was the top pellet of the three test pellets in all but one test (Test 13). UO_2 insulator pellets were placed on both sides of the test pellets to complete the pellet stack.

Pellets 0.850 ± 0.05 inch o.d. and 0.450 ± 0.05 inch in height were made by granulating the compacted powders through a coarse screen followed by cold pressing and sintering in dry N_2 -6% H_2 at 1650°C to produce annular pellets with 84 to 97.6% T.D. and O/M = 1.95. The pellets were centerless ground to ensure that a right circular cylindrical shape was maintained. The central annuli were 0.200 inches in diameter so that the pellets could be stacked in a column on the 0.1875 inch diameter tungsten heater rod.* The pellets were slotted along a radius to prevent breakage from differential thermal expansion. Black-body holes 0.030 to 0.050 inches in diameter were drilled at 0.120, 0.180, 0.240, and 0.300 inch depths in each pellet. The holes had length to diameter (L/D) ratios from 4 to 6.

* No provision was made to maintain concentricity of the annular pellets with respect to the tungsten heater rod. Electrical contact was possible and is considered in Section 5.4.

71-5

Figure 6. Experimental Arrangement

4.3 INSTRUMENTATION

A Pyro disappearing filament optical pyrometer was used to measure the black-body hole temperatures. Pyrometer readings were standardized against tungsten/tungsten-26% rhenium thermocouples inserted into a cavity in the test pellet. Standardization measurements were carried out under isothermal conditions. Optical pyrometer measurements were limited to maximum temperatures of approximately 2200° to 2400°C because of fuel vaporization and the corresponding distortion of the black-body holes.

Total current through the tungsten rod heater was measured with a Weston multirange Ammeter (0 to 1 up to 0 to 50 amperes, $\pm 1/4\%$ accuracy) in series with a 240/1 stepdown transformer.

4.4 EXPERIMENTAL PROCEDURE

Three test pellets were positioned on the tungsten heater rod with 7 UO_2 insulator pellets below and 6 UO_2 insulator pellets above them to minimize axial heat losses. The loaded rod was inserted into the furnace so that the bottom of the rod was suspended freely in the indium-gallium pool. The bottom insulator pellet rested on the ledge of the liquid metal pool. The three test pellets were positioned so that the black-body holes could be observed through the slit in the furnace door.

The furnace was evacuated to $\sim 10^{-1}$ mm Hg and back filled with dry He-6% H_2 a minimum of three times to provide a low enough oxygen pressure so that it would be easily gettered by the hydrogen in the furnace atmosphere without significantly affecting the $\text{H}_2\text{O}/\text{H}_2$ ratio.

Thermal conductivity measurements were conducted by energizing the tungsten mesh and rod heaters simultaneously at zero power and slowly increasing both simultaneously until a temperature of approximately 800°C was observed at the pellet surface and the temperature difference between the deepest and most shallow black-body holes was about 200°C. The radial temperature difference in the test pellets was held to a maximum of 200°C and to a maximum of 50°C between adjacent black-body holes. This should have minimized any oxygen migration from the hotter to the cooler regions of the pellets. Further temperature increases were carried out using the mesh heater alone, so that the power input to the center of the pellet stack remained relatively constant. Steady-state was reached quite rapidly (within 10 minutes). Temperatures were measured with a disappearing filament micro-optical pyrometer focused on the bottoms of the four radial holes, drilled to different depths in the specimen. The entire set of black-body holes was measured in sequence; then the sequence was repeated at least four times. When five consecutive measurements of each black-body hole were within ± 5 degrees, those five measurements were concluded to be at steady state. The next series of measurements was then made after increasing the furnace temperature. Current measurements are taken after each furnace temperature increase (see Section 6.1).

Measurements for the urania-plutonia system encompassed the following conditions: densities of 84 to 97.6% T.D., O/M ratios of 1.94 to 2.00, plutonium contents of 0 to 100%, temperatures of 800 to $\sim 2300^\circ\text{C}$, and two fuel preparation methods—coprecipitation and physically-mixed. Only the 20% plutonium content data were ultimately used to develop the empirical equation.

Measurements at various stoichiometries were made by annealing the test pellets to obtain a stoichiometry of 1.940. The precise weight of each pellet was measured at this time. Thermal conductivity measurements were made from 800 to 2300°C while the test pellets were surrounded by a tantalum sleeve to retain the low stoichiometry. The pellets were then cooled and removed from the furnace for weighing. The pellets were then placed again in the furnace and annealed in dry He-6% H_2 for two hours at 1600°C after which thermal conductivity measurements were again carried out from 800 to 2300°C. The weighing procedure was repeated and the pellets were annealed for two hours in He-6% H_2 to which a small amount of H_2O was added. Thermal conductivity measurements from 800 to 2300°C were repeated in this atmosphere.

The weighing procedure was again repeated and the pellets were annealed in He-6% H_2 saturated with room temperature H_2O for 2 hours at 1600°C. Thermal conductivity measurements were then carried out in this atmosphere from 800 to 2300°C. In this manner thermal conductivity measurements were made at stoichiometries of 1.940, 1.948, 1.980, and 2.00.

The test parameters are summarized in Table 1.

Table 1
SUMMARY OF TEST PARAMETERS

Test Number	Number of Pellets	Starting ^a Material	Wt % Pu	O/M	Density Range (% T.D.)	Temperature Range (°C)	Comments
1	7	C	20	1.95	92.78-93.1	1200-2300	Results Not Used
2	11	C	20	2.00	92.78-93.1	800-2300	Results Not Used
3	12	PM	30	2.00	93.28-93.41	800-2300	
4	31	PM	20	1.95	92.12-92.7	800-2300	Results Not Used
				2.00			
5	27	PM	20	1.95	94.58-95.03	800-2300	Results Not Used
				2.00			
6	5	PM	20		91.26-97.6	800-1200	Column Too Short
7	6	-	0	2.00	97.63	800-1800	100% UO ₂
8(I)	8	PM	20	1.94	91.0	800-1400	One Pellet Was UO ₂ ^b
				1.95			
8(II)	9	PM	20	1.98	91.0	800-1450	One Pellet Was UO ₂ ^b
				2.00			
8(III)	8	PM	20	1.95	91.0	800-2300	One Pellet Was UO ₂ ^b
10	8	PM	20	1.96	84.0	800-2300	One Pellet Was UO ₂ ^b
11	8	C	20	1.965	85.5 - 86.9	800-2300	One Pellet Was UO ₂ ^b
12	6	PM	100	1.86	97.6	800-2000	One Pellet Was UO ₂ ^b
13	8	PM	0/10	1.986	91.0 - 97.6	800-2300	One Pellet Was UO ₂ ^b

(a) C = Coprecipitated powder, PM = physically-mixed powder

(b) The UO₂ pellet was 97.6% T.D. and O/M = 2.00

5. RESULTS AND DISCUSSION

Thermal conductivity measurements were carried out on specimens of urania-plutonia mixtures as functions of temperature, stoichiometry, density, composition and fabrication procedure. The results are discussed in terms of current theories on phonon transfer in solids. An empirical equation given in Section 7 was generated which described that part of the data which involved changes in microstructure, temperature and stoichiometry.

5.1 EFFECT OF STOICHIOMETRY AND COMPOSITION ON THE THERMAL CONDUCTIVITY OF URANIA-PLUTONIA

The effects of stoichiometry on the thermal conductivity of physically blended UO₂-20% PuO₂ are shown in Figure 7. This experiment was conducted from 800°C to 2300°C on a single set of pellets by varying the oxygen activity in the furnace atmosphere in accordance with the experimental procedure discussed in Subsection 4.4. Measurements were made at stoichiometries varying from 1.94 to 2.00. The results exhibited the expected increase in thermal conductivity as the stoichiometry increases at low temperatures. This is in accordance with the thermal diffusivity measurements of Gibby,⁴ and Van Craeynest and Weilbacher⁵ who found a monotonic increase in thermal diffusivity as the stoichiometric composition is approached.

The strong effect of stoichiometry on the thermal conductivity of the mixed oxide material is worthy of further comment. At temperatures much greater than the Debye temperature, the thermal conductivity is largely dependent upon the phonon mean free path length. As this path length is reduced, phonon scattering becomes more pronounced with a resulting decrease in thermal conductivity, following roughly a T^{-1} dependence on the temperature. When the mean free path is reduced to interatomic distances, further reduction of path length has no effect and the thermal conductivity becomes temperature independent. This condition apparently exists in (U, Pu)O_{2-x} at temperatures above about 1400°C as indicated by the data discussed here. Below this temperature, the thermal conductivity increases with decreasing temperature and is also highly dependent upon impurity scattering centers such as oxygen vacancies. The stoichiometry and composition dependences in the thermal conductivity data indicate that the phonon mean free path is reduced to interatomic distances with only about 3% of the oxygen sub-lattice replaced by vacancies.

As additional vacancies are introduced, either by lowering the oxygen activity or by increasing the plutonium content, the thermal conductivity does not continue to decrease. The constancy of the thermal conductivity for large oxygen vacancy concentrations also strongly supports the hypothesis that the substitution of plutonium for uranium does not alter the lattice vibrational spectrum significantly. That this is the case is illustrated in Figure 8 which exhibits the thermal conductivity as a function of composition for hypo-stoichiometric urania-plutonia of a constant oxygen-to-plutonium ratio. Experiments were performed on specimens of urania-plutonia with plutonium compositions of 10, 20, 30 and 100%. In each case the experiments were carried out in dry He-6% H₂ so that conditions of constant oxygen-to-plutonium ratio prevailed at each test temperature. The oxygen-to-plutonium ratios varied from approximately 1.82 at 800°C to 1.65 at 2300°C, assuming that equilibrium with the furnace gas took place at each temperature during the test.

Corresponding O/M's varied (e.g., for constant 20% plutonium composition) from 1.96 at 800°C to 1.93 at 2300°C. Gibby⁴ has indicated that the addition of plutonium to the UO₂ lattice had virtually no effect on the thermal conductivity except where it altered the defect concentration in the oxygen sub-lattice. He has reported data on thermal diffusivity in urania-plutonia solutions as a function of plutonium content, and the relatively small effects reported would be completely over-shadowed by the larger number of impurity scattering centers due to the anion defect structure in the hypostoichiometric mixed oxide material.

5.2 EFFECT OF FABRICATION PROCEDURE OF THE THERMAL CONDUCTIVITY OF (U_{0.8}Pu_{0.2})O_{2-x}

While most of the materials studied in this work were prepared by physically blending the urania and plutonia powders in the proper proportions, some tests were carried out on material which was derived from a coprecipitation process, as described in the section on "experimental design." Figures 9 and 10 show comparisons of thermal conductivity measurements in urania-plutonia fabricated using physically blended and coprecipitated powders. Any differences observed here were generally within experimental error, and are contained within the confidence band on the empirical equation. The thermal conductivities of these materials might be expected to be different if the plutonia agglomerates were of sufficient size to result in the material being basically a matrix of UO₂ with large islands of hypostoichiometric plutonia. This situation would probably result in somewhat higher conductivity observed for the physically blended material. Since this is not the case, it can be assumed that the plutonia was sufficiently well distributed so that these inhomogeneous effects were generally not present.

5.3 EFFECT OF DENSITY ON THE THERMAL CONDUCTIVITY OF (U_{0.8}Pu_{0.2})O_{2-x}

The effect of density on the thermal conductivity of urania-20% plutonia is illustrated in Figure 11. Contrary to the normal models of porosity effects on thermal conductivity, no significant density effect on the thermal conductivity was observed in these measurements. Since all of the available theoretical models concerning porosity in thermal conductivity measurements are based on the assumption of closed porosity, the presence of open pores and fissures in this material would preclude an analysis based on these theoretical models. It is likely that the ratios of open to closed porosity in the various materials tested are such that any large density variation, such as would be predicted by any of the theoretical models, are not apparent. The low stoichiometry (1.95 o/m) overshadowed the density effect in this case (Subsection 5.5).

5.4 ELECTRICAL CONDUCTIVITY

The electrical conductivity of mixed oxide fuels varies with stoichiometry and plutonium content such that it increases with increasing stoichiometry and with increasing plutonium contents. The samples were tested in dry hydrogen, which fixed the O/Pu ratio at each temperature while electrical conductivity increased with increasing temperature. Increasing plutonium content would result in greater electrical conductivity although offset to some extent by any decrease in stoichiometry. An increase in electrical conductivity would have caused some amounts of joule heating if the pellets had come in contact with the central tungsten heating rod. Although the electrical conductivity of tungsten is much larger than that of a urania-plutonia ceramic, this might explain to some extent the wide variations in thermal conductivity observed at high temperatures for the 30 to 100% PuO₂ samples, shown in Figure 8.

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Figure 7. Effect of Stoichiometry on Thermal Conductivity of $(U_{0.8}Pu_{0.2})O_{2-x}$

Figure 8. Effect of Composition on Thermal Conductivity of $(U_xPu_y)O_{2-z}$

71-8

Figure 9. Fabrication Effect on Thermal Conductivity of $(U_{0.8}Pu_{0.2})O_{1.95}$

Figure 10. Thermal Conductivity of Coprecipitated and Physically Mixed Pellets

71-9

5.5 ORDER-DISORDER

The thermal conductivity of a solid decreases with decreasing density and increasing molecular disorder. The disorder effect increases with temperature up to the temperature at which radiative heat transfer effects dominate and cause the observed increase in thermal conductivity at high temperatures. In mixed oxide fuels, increasing disorder can be caused by the formation of a non-ideal solid solution, such as one containing scattering centers formed due to oxygen vacancies. The number of oxygen vacancies depends on the stoichiometry (O/M ratio) of the fuel and not the O/Pu ratio. Test 8 of this work demonstrated the effect of this increase in thermal conductivity due to increases in O/M. The magnitude of the effect decreased as the deviation from stoichiometry (O/M = 2.00) increased and as the temperature increased. With increasing plutonium content, disorder also increased but the effect was overshadowed by disorder resulting from an increased number of oxygen vacancies since the measurements were made at low O/M values for plutonium content greater than 20%. Also overshadowed by the effect of stoichiometry was the effect of density on thermal conductivity. Thus the results presented indicate the strong effect of stoichiometry and a lesser effect of plutonium content and density. For this reason, plutonium content was not included as a parameter in the empirical equation and the density correlation factor of 0.4465 developed by Asamoto¹ was retained. The second term of the empirical equation given in Section 7 reflects a much lesser effect of density on thermal conductivity than was observed in the UO₂ study by Asamoto.

5.6 EMPIRICAL EQUATION FOR THE THERMAL CONDUCTIVITY (U_{0.8}Pu_{0.2})O_{2-x}

Figure 12 shows the plot of the empirical equation developed for the thermal conductivity of 91% dense (U_{0.8}Pu_{0.2})O_{2-x} which is given in Section 7, as a function of temperature over the range of 800 to 2300°C. The increase in the thermal conductivity observed above ~1800°C was predicted by the equation. The 90% confidence band has been shown in Figure 12 to indicate the statistical accuracy of the equation. A few selected data points have been added to Figure 12 to illustrate the curve-fitting technique. The experimental uncertainty associated with each of these data points has been indicated in the figure by a vertical bar. These uncertainties were used as the weighting factors in the statistical analyses discussed in Section 6.1.

Figure 13 shows the empirical equation plotted for 91% dense (U_{0.8}Pu_{0.2})O_{2-x} and varying stoichiometry as a function of temperature. The effect of changing stoichiometry discussed in the preceding sections is evident here.

5.7 MICROSTRUCTURES OF TESTED SPECIMENS

Metallographic examinations were conducted on selected thermal conductivity test specimens to determine the extent of fuel restructuring during the high temperature portions of the thermal conductivity measurements. Two examples are presented where varying degrees of restructuring occurred. Figure 14 illustrates the microstructure of 84% dense (U_{0.8}Pu_{0.2})O_{1.95} subjected to a radial temperature gradient with a central temperature > 2400°C for 40 minutes. Extensive pore migration was evident in the center which extended to about 2200°C. Had the test continued for a longer period, a mature columnar grain growth region would have formed.

Figure 15 shows the microstructure of 94.6% dense (U_{0.8}Pu_{0.2})O_{1.95} subjected to a radial temperature gradient with a center temperature > 2378°C for 20 minutes.

Barely perceptible evidence for pore migration above 2200°C was visible. The shorter test time combined with the higher density and smaller pore size served to inhibit pore movement to the extent that only negligible amounts were seen.

The minimum temperature observed for pore migration was somewhat higher than that observed for UO₂ specimens subjected to similar treatments. Asamoto¹ and Lawson¹³ have reported pore sweeping in UO₂ at temperatures greater than 1950°C. Possibly with longer heat treatments the mixed oxide would have exhibited pore migration at lower temperatures. However, the lower heavy metal-bearing vapor pressures in the hypostoichiometric mixed oxide tended to delay the kinetics of pore migration to the extent that the onset of observable pore movement was permanently shifted to higher temperatures.

Figure 16 (a) and (b) compare the microstructures of test specimens prepared by different powder preparation methods. Figure 16 (a) shows coprecipitated 87% dense (U_{0.8}Pu_{0.2})O_{1.95} and Figure 16 (b) shows physically-mixed 94.6% dense (U_{0.8}Pu_{0.2})O_{1.95}. Both figures indicated that, as a result of the small temperature gradient, little grain growth occurred. Grains of comparable characteristics were observed in the two figures, which represent regions of comparable temperature.

The microstructures shown in Figures 14, 15, and 16 can be considered typical of all the tests done in this study.

Figure 11. Effect of Density on Thermal Conductivity of $(U_{0.8}Pu_{0.2})O_{1.95}$

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Figure 12. Thermal Conductivity of 91% Dense $(U_{0.8}Pu_{0.2})O_{2.00}$ Showing 90% Confidence Band and a Few Selected Data Points with Experimental Uncertainty Bands

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71-12

Figure 13. Effect of Stoichiometry on the Thermal Conductivity of 91% Dense $(U_{0.8}Pu_{0.2})O_{2-x}$

71-13

Figure 14. Post-Test Microstructure of 84% Dense $(U_{0.8}Pu_{0.2})O_{1.95}$

Figure 15. Post-Test Microstructure of 94.6% Dense $(\text{U}_{0.8}\text{Pu}_{0.2})\text{O}_{1.95}$

250X

NEGATIVE No. 0827

(a) PREPARED AS COPRECIPITATED 87% T.D. $(U_{0.8}Pu_{0.2})O_{1.965}$
 PELLET i. d. B486-2

250X

NEGATIVE No. 0828

(b) PREPARED AS PHYSICALLY-MIXED 94.6% T.D. $(U_{0.8}Pu_{0.2})O_{1.95}$
 PELLET i. d. M0090-8

71-15

Figure 16. Comparison of the Microstructures of Test Specimens

6. DATA ANALYSIS

6.1 METHOD OF DATA ANALYSIS

Each test pellet had four black-body holes, and a maximum of five temperature measurements were taken at each of the holes. The current (I) through the tungsten rod was measured once for each run of sixty (maximum) temperature measurements. Attempts to measure the voltage through the tungsten rod were futile since the temperature (which thus determined the rod power by multiplying $E \times I$) was not uniform over the entire length of the rod. Rod temperature however was assumed to be uniform throughout the test pellet stack. Also, voltage tap connections to the tungsten rod were difficult to attain due to the high temperatures involved. A single test thus consisted of up to twenty temperature measurements for each pellet and up to three pellets per test. Black-body hole depth measurements (r) were recorded before and after testing to an accuracy of ± 1 mil. If a significant deviation in hole depth was found in a particular hole, the temperature data for that hole were deleted. The time of each temperature measurement was recorded at the beginning of each sequence of measurements (i.e., after twelve consecutive measurements).

The data taken from each set of up to four black-body holes was plotted as temperature versus log radius. This yielded up to twenty points in an approximate straight line, assuming a constant thermal conductivity yield a parabolic temperature profile in a cylindrical pellet. Inconsistencies in black-body hole depths (pellet radii) were recognized if points in these plots deviated from the best fit line. General consistency of the data was also judged from these plots, which formed a basis for deleting several tests (see Table 1). Since there were different fuel materials in each test column (UO_2 and PuO_2 have different thermal conductivities) and because of general furnace heating variations, an axial temperature gradient existed across the test column. However, the only axial temperature gradient of importance was the one which existed across the length of each individual pellet. Measurements showed that this gradient could be a maximum of 10°C , but usually only about 5°C over the entire length of a pellet. The resultant actual temperature gradient between black-body holes at equal depths was negligible. A least-squares line was fit through the data remaining using computer code technique. The code extrapolated the best-fit line through the origin ($r = 0$) or pellet inside diameter which determined the center temperature as well as the various ΔT 's and Δr 's for each pellet. This was done by next calculating the gap conductivity of the helium gas filling the space between the pellet's inside diameter and tungsten rod.¹⁴ Using this, the temperature drop between the pellet's inside diameter and tungsten rod were determined and the rod temperature, assumed to be uniform, was calculated. An empirical equation¹⁵ of resistance of unalloyed tungsten as a function of temperature was used to calculate the resistance of the tungsten rod which then yielded the power (Q) in the rod by means of the $Q = I^2 R$ relation. The same value of Q was used for all five observations at each black-body hole.

A least-squares line was fit through each set of up to four consecutive temperature measurements, one for each of the four black-body holes per pellet. Thirty seconds elapsed between consecutive temperature measurements, but about six minutes elapsed between measurements at the same hole. For up to five measurements per hole, up to five least-squares lines were obtained for each pellet. These least-squares plots consisted of lines of temperature versus log r as before. Temperature differences were calculated from the equations of these least-squares lines, and using the slopes of the lines, up to five values of thermal conductivity (k) were determined in a manner outlined in detail by Asamoto.¹ The validity of such a procedure depended upon provisions which were made to hold the radial temperature differences between adjacent black-body holes to a maximum of about 50°C (see Section 4.4) so that a mean value of the thermal conductivity could be assumed within such a temperature region.

In such a manner, values for k were calculated for the various tests under varying conditions of temperature (as controlled by varying the power in the tungsten heater rod), O/M ratio, and density. Only the results of tests 8(I), 8(II), 8(III), 10 and 11 (396 data points) were used to determine an empirical equation and comprise only 20% Pu concentration fuel. Except for test numbers 3 and 7, test data prior to test number 8 (see Table 1) were not reported due to inconsistencies and/or uncertainties in the black-body holes measurements. Although the data of test numbers 3, 7, 12 and 13 (which were for plutonium concentrations of 0 [UO_2], 10, 30 and 100 percent) were not used to fit the empirical equation, they were, however, discussed in the results. These tests were not used for determining the equation because a consistent relationship between thermal conductivity and plutonium content for hypo-stoichiometric fuel could not be established.

In order to fit an equation to the 396 data points (see Appendix A for data listing) which were valid, a computer code was developed to perform a weighted regression analysis for a non-linear equation form.

From experiments such as this, thermal conductivity of mixed oxide fuel has been found to be a function of several variables. These variables include: temperature, fuel density, plutonium content, and oxygen/metal (O/M) ratio. Theoretical models along with prior work set the guidelines for the general form of the equation:

$$k = C_1 + \frac{1}{(C_2 - 0.4465D)T} + C_3 T^3 + \frac{C_4}{(2.04 - O/M)T^2}$$

where

k = thermal conductivity (watts/cm²·°C)

T = temperature (°C)

D = fractional density

O/M = oxygen/metal ratio

C_i = constants determined by data analysis ($i = 1-4$)

The factor (0.4465) multiplying the density (D) in the second term of the equation was derived from prior work by Asamoto¹ on UO_2 . Insufficient data prohibited the determination of such a factor for mixed oxide fuel here. The factor (2.04) in the denominator of the last term was determined empirically.

The T^3 term was required to produce the observed increase in thermal conductivity at high temperatures. Linear (T) and T^2 relationships were tried first, but it was found that the T^3 relationship was the most satisfactory. Caution is noted regarding any extrapolation of the equation above 2300°C (i.e., above the upper limit of experimental data) which might result in an overprediction of the thermal conductivity as a result of this T^3 term.

A weighted regression analysis was required since not all data points were known with equal precision. Those at lower temperatures were less precise than at higher temperatures. This was due to experimental errors which are explained in Section 6.3.1. The computer code which was developed fit an equation of the form discussed here to the entire set of data by determining the constants C_i such that the equation described the data to within acceptable limits (see Section 6.3). It is not the purpose of this report to give a detailed description of the mathematics which were involved. However, initial estimates for the constants C_i were required for the curve-fitting analysis. These estimates were determined using both hand calculations and a generalized (non-weighted) curve fitting computer code. Only "ball-park" estimates were required and were easily obtained. These initial guesses were:

$$C_1 = 0.01, C_2 = 0.5, C_3 = 1 \times 10^{-13}, \text{ and } C_4 = 1.0 \times 10^3$$

The variation of k with various powers of T was determined by noting trends on plots of k versus T as a function of D , O/M , etc. Intuition entered also, as in the case of the $C_3 T^3$ term which was required to fit the curve to the high temperature data which showed a slight increase in k as a function of T . The factor 2.04 in the last term was determined by hand calculations at first, but later it was allowed to float as a fifth constant in the computer calculations and the value of 2.04 was confirmed.

The detailed weighted non-linear regression analysis yielded final values for the four constants of: $C_1 = 1.524 \times 10^{-2}$, $C_2 = 0.9702$, $C_3 = 0.5841 \times 10^{-12}$ and $C_4 = 360.2$ to form the final equation reported here. The computer code also yielded statistical parameters which are discussed in Section 6.3, and a plotting routine was also included.

6.2 DEGREE OF UNCERTAINTY IN RESULTS

6.2.1 Mixed Oxide Thermal Conductivity Experimental Error Analysis

This analysis of errors in thermal conductivity measurements was based on the general probable error equation.

$$P^2 = \left(P_x \frac{\partial z}{\partial x} \right)^2 + \left(P_y \frac{\partial z}{\partial y} \right)^2 + \dots$$

when $z = f(x, y, \dots)$ is the function for which the probable error is to be determined and $P_x, P_y, \dots$ are the probable errors attached to the given variables.

The equation for thermal conductivity of a cylindrical material with radial heat flow is:

$$K = \frac{Q}{2\pi} \frac{(\ln r_2 - \ln r_1)}{(T_1 - T_2)} = \frac{Q}{2\pi} \frac{\ln(r_2/r_1)}{\Delta T}$$

The variables of interest are Q , r_1 , r_2 , and ΔT .

The partial derivatives are:

$$\frac{\partial K}{\partial Q} = \frac{\ln(r_2/r_1)}{2\pi (\Delta T)}$$

$$\frac{\partial K}{\partial r_2} = \frac{Q}{2\pi \Delta T} \left(\frac{1}{r_2} \right)$$

$$\frac{\partial K}{\partial r_1} = \frac{Q}{2\pi \Delta T} \left(\frac{1}{r_1} \right)$$

$$\frac{\partial K}{\partial (\Delta T)} = - \frac{Q}{2\pi} \ln(r_2/r_1) \left[\frac{1}{(\Delta T)^2} \right]$$

and the error equation becomes:

$$P^2 = P_Q^2 \left[\frac{\ln(r_2/r_1)}{2\pi \Delta T} \right]^2 + P_{r_2}^2 \left(\frac{Q}{2\pi (\Delta T) r_2} \right)^2 + P_{r_1}^2 \left(\frac{Q}{2\pi (\Delta T) r_1} \right)^2 + P_{\Delta T}^2 \left(\frac{Q \ln(r_2/r_1)}{2\pi (\Delta T)^2} \right)^2$$

Consider first the probable error in power (Q) determined by errors in assignment of the tungsten rod temperature (the actual voltage and current measurements were known to a higher order of precision).

The temperature drop between the tungsten rod and the fuel inside diameter was largely determined by the He gas conduction in the gap. The thermal conductivity of He at various temperatures was calculated from equations given by Hirschfelder.¹⁴

The results of these calculations are shown below:

$T^\circ K$	K_{He} (watts/cm $^\circ K$)
1000	3.41×10^{-3}
1500	4.60×10^{-3}
2000	5.33×10^{-3}
2500	6.19×10^{-3}

The error in power (Q) was calculated as follows: The UO_2 data from tests 8 and 13 were compared with Asamoto's¹ data, finding that difference between data was no more than 0.00125 at 800°C. Since $K_{UO_2} \approx 0.04$, then for this data $K_{UO_2} \approx 0.04 \pm 0.00125$ which represents a 3.1% error at 800°C. This corresponded to a temperature error at the tungsten rod of $\pm 25^\circ C$. The gap width between the rod and the pellets was calculated for a total temperature drop of 50°C as follows:

$$\ln r_2 = \ln r_1 + \left(\frac{2\pi K}{Q_L} \right) \Delta T_{gap}$$

where K is conductivity of He, using a hypothetical Q_L which remained constant for this gap analysis.

$$\ln r_2 = \ln (0.0938 \times 2.59) + \frac{2\pi \times 3 \times 10^{-3} \times 50}{50}$$

$$\ln r_2 = \ln (0.238) + 1.88 \times 10^{-2}$$

$$\ln \left(\frac{r_2}{r_1} \right) = 1.88 \times 10^{-2}$$

$$\frac{r_2}{r_1} = e^{1.88 \times 10^{-2}} = 1.01005 \times 1.0088 = 1.019$$

$$r_2 = 1.019 \times 0.0938 = 0.0956$$

or a gap of 1.8 mils on the average. Using this gap and a Q_L of 50 watts/cm $^\circ C$, ΔT 's were calculated for higher temperatures using adjusted K_{He} values as well.

Once the temperature drops across the gap were known for each rod temperature, the error in rod temperature was calculated as

$$\pm \frac{\Delta T_{\text{gap}}}{2T_{\text{rod}}}$$

Since the resistivity of tungsten varied linearly with temperature, this error was also the error in linear power, which is plotted in Figure 17 as P_Q .

Figure 17. Uncertainties in Heat Flux Measurements as a Function of Temperature

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Errors due to the uncertainty in ΔT between measured points were also present and comparable to the error in Q , but to be conservative, the entire error was attributed to uncertainties in Q . This yielded a value for the ΔT across the gap at 800°C of 50°C. Using this ΔT and the conductivity values for He as a function of temperature, an effective gap width was calculated. Then new ΔT and error values were calculated. The results of these calculations are shown in Figure 17.

The probable errors in the radii of black-body holes were calculated on the basis of $Pr_1 = Pr_2 = \pm 1$ mil.

The probable errors in ΔT were found based upon the reproducibility of individual temperature measurements using optical pyrometry. It has been shown that measurements such as these are reproducible (i.e., the variation among a series of temperature measurements at the same point compared with the one most often obtained) to within $\pm 3^\circ\text{C}$.² There may well have been a systematic error in the temperature measurements. If a black-body cavity (hole) started out with a temperature not constant over its surface, it could be postulated that radiative transfer would have brought the walls close to a uniform temperature. If such a mechanism existed, then the temperature measured would have been lower than the maximum temperature without radiative transfer. Such a systematic error would not affect ΔT however. The variation in the absolute values of individual optical pyrometer measurements has been shown to be $\pm 2\%$ up to 2000°C and $\pm 3\%$ between 2000°C and 2400°C.¹ The probable error in ΔT , called $P_{\Delta T}$, was then just the square root of the sum of the squares of the error in reproducibility for two temperature measurements, $\pm (3^2 + 3^2)^{1/2}^\circ\text{C}$, or about $\pm 4^\circ\text{C}$.

Then the squares of all the error terms were summed and the resulting probable error in K was the square root of that sum. It can be noted here however, with respect to the relative importance of the sources of experimental error, that the error due to uncertainties in Q was more than one order of magnitude greater than the errors due to uncertainties in either black-body hole depth or ΔT .

6.2.2 Confidence Limits

The weighted regression analysis which was used to fit an equation to the data reported here was designed to also calculate a 90% confidence band on the equation. The computer code combined the experimental error associated with each data point (which were used as "weighting factors") with the error involved the deviations of each data point from the regression line. Results are tabulated in Appendix B, and it was apparent that the width of the confidence band at each data point was not the same since the experimental conditions varied.

The "independent variable" listed is temperature and the "dependent variable" is thermal conductivity. Percent error width for each data point is listed in the final column. The 90% confidence limits were placed on the equation determined using one-half the mean value of the percent error widths of all 396 data points. This in effect gave a reasonably conservative 90% confidence band of uniform width for the entire equation. It must be remembered that not all data points need to fall within a 90% confidence band. This is especially true in a weighted regression analysis like the one which was done here, since some points were known more precisely than others.

7. CONCLUSIONS

1. The thermal conductivity of $(0.2 \text{ Pu} - 0.8 \text{ U})\text{O}_{2-x}$ was found to be a function of several variables. The equation is

$$k = 0.01524 + \frac{1}{(0.9702 - 0.4465D)T} + (0.5841 \times 10^{-12})T^3 + \frac{360.2}{(2.04 - O/M)T^3}$$

where

k = thermal conductivity (watts/cm-°C)

T = temperature (800 to 2300°C)

D = fractional density (0.84 to 0.91)

O/M = oxygen/metal ratio (1.940 to 2.000)

2. The thermal conductivity of mixed oxide fuel was found to increase slightly at temperatures greater than about 1800°C.
3. For design purposes, 90% confidence limits of $\pm 11\%$ may be applied to the above equation as determined by a weighted regression analysis.
4. The application of the out-of-pile thermal conductivity data from this experiment to in-pile usage requires additional input from integral to melt thermal conductivity data to ensure that the required boundary conditions are fully met.^{16,17}

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REFERENCES

1. Asamoto, R. R., Anselin, F. L., and Conti, A. E., *The Effect of Density on the Thermal Conductivity of Uranium Dioxide*, April 1968 (GEAP-5493).
2. Hetzler, F. J., Lannin, T. E., Perry, K. J., and Zebroski, E. L., *The Thermal Conductivity of Uranium and Uranium-Plutonium Oxides*, August 1967 (GEAP-4879).
3. Schmidt, H. E., and Richter, J., *The Influence of Stoichiometry on the Thermal Conductivity of $(U_{0.8}Pu_{0.2})O_{2\pm x}$* Oxide Fuel Thermal Conductivity Symposium, Stockholm, Sweden, June 1, 1967.
4. Gibby, R. L., "The Effect of Plutonium Content on the Thermal Conductivity of $(U,Pu)O_2$ Solid Solutions," *J. Nucl. Mat.* 38: 163-177 (1971).
5. Van Craeynest, J. C., and Weilbacher, J. C., *Etude De La Conductibilite Thermique Des Oxydes Mixtes D'Uranium Et De Plutonium*, *J. Nucl. Mat.* 26: 132-136 (1968).
6. Baily, W. E., et al., *Thermal Conductivity of Uranium-Plutonium Oxide Fuels*, Nuclear Metallurgy, Volume 13, International Symposium on Plutonium Fuels Technology, Proceedings of the 1967 Nuclear Metallurgy Symposium, Scottsdale, Arizona, October 4-6, 1967, AIME.
7. Gibby, R. L., *The Effect of Oxygen Stoichiometry on the Thermal Diffusivity and Conductivity of $U_{0.75}Pu_{0.25}O_{2-x}$* , January 1969 (BNWL-927).
8. Ainscough, J. B., "The Effect of Electrical Conduction in UO_2 on the Measurements of its High Temperature Thermal Conductivity as Determined by Radial Flow Techniques," *J. Nucl. Mat.* 20, pp. 184-192 (1966).
9. Schmidt, H. E., "Some Considerations on the Thermal Conductivity of Stoichiometric Uranium Dioxide at High Temperatures," *J. Nucl. Mat.* 39:pp. 234-237 (1971).
10. Kruger, O. L., Savage, H., "Heat Capacity and Thermodynamic Properties of Plutonium Dioxide," *J. of Chemical Physics* (49) 4540 (1968).
11. Hein, R. A., and Flagella, P. N., *Enthalpy Measurements of UO_2 and Tungsten to 3260°K*, February 16, 1968, (GEMP-578).
12. Ogard, A. E., and Leary, J. A., *High Temperature Heat Content and Heat Capacity of Uranium Dioxide and Uranium Dioxide-Plutonium Dioxide Solid Solutions*, LA-DC-8620 (1967).
13. Lawson, V. B., and MacEwan, J. R., *Thermal Simulation Experiments with a UO_2 Fuel Rod Assembly*, March 1960 (CRFD-915).
14. Hirschfelder, J. O., et al., *Molecular Theory of Gases and Liquids*, John Wiley & Sons, Inc., New York, New York, (1954), p. 534.
15. Feith, A. D., *The Thermal Conductivity and Electrical Resistivity of Tungsten-26 Weight Percent Rhenium*, 1967 (GEMP-562).
16. Craig, C. N., and Baily, W. E., *In-Pile Comparison of Effective Thermal Conductivity of (PuO_2-UO_2) Mixed Oxides*, January 1968 (GEAP-5556).
17. Cantley, D. A., Rubin, B. F., and Craig, C. N., *Stoichiometric Effects on the Integrated Thermal Conductivity of Mixed Oxide Fuels*, to be published (GEAP-13734).

APPENDIX A. DATA

The tables found in Appendix A contain the following information: thermal conductivity (K , $W/cm^{\circ}C$), temperature ($^{\circ}C$), fractional density, fractional plutonium content, test number, and a data point reference number. For the 20% Pu data, the weighting factors used for the weighted non-linear regression analysis have been included.

Each table of data has been plotted with a figure number corresponding to the data tables. In the figures with 20% Pu data a smooth curve of the empirical equation has been plotted.

Table A-1
TEST 8 (PART I) DATA

K	Temperature (°C)	Density	O/M	Pu	Weight	Test Number	Number
0.0202	954	0.91	1.940	0.20	0.001892	8.201	0001
0.0199	953	0.91	1.940	0.20	0.001863	8.201	0002
0.0200	951	0.91	1.940	0.20	0.001873	8.201	0003
0.0200	948	0.91	1.940	0.20	0.001873	8.201	0004
0.0199	946	0.91	1.940	0.20	0.001863	8.201	0005
0.0193	1125	0.91	1.940	0.20	0.001195	8.202	0006
0.0192	1126	0.91	1.940	0.20	0.001189	8.202	0007
0.0193	1126	0.91	1.940	0.20	0.001195	8.202	0008
0.0195	1126	0.91	1.940	0.20	0.001207	8.202	0009
0.0197	1125	0.91	1.940	0.20	0.001220	8.202	0010
0.0195	1202	0.91	1.940	0.20	0.001045	8.203	0011
0.0196	1203	0.91	1.940	0.20	0.001051	8.203	0012
0.0192	1205	0.91	1.940	0.20	0.001029	8.203	0013
0.0193	1203	0.91	1.940	0.20	0.001035	8.203	0014
0.0194	1204	0.91	1.940	0.20	0.001040	8.203	0015
0.0200	1347	0.91	1.940	0.20	0.000892	8.204	0016
0.0197	1348	0.91	1.940	0.20	0.000878	8.204	0017
0.0196	1346	0.91	1.940	0.20	0.000874	8.204	0018
0.0199	1347	0.91	1.940	0.20	0.000887	8.204	0019
0.0195	1347	0.91	1.940	0.20	0.000870	8.204	0020
0.0210	895	0.91	1.940	0.20	0.001974	8.301	0021
0.0213	893	0.91	1.940	0.20	0.002002	8.301	0022
0.0207	893	0.91	1.940	0.20	0.001946	8.301	0023
0.0213	892	0.91	1.940	0.20	0.002002	8.301	0024
0.0216	890	0.91	1.940	0.20	0.002030	8.301	0025
0.0236	1076	0.91	1.940	0.20	0.001476	8.302	0026
0.0236	1076	0.91	1.940	0.20	0.001476	8.302	0027
0.0233	1077	0.91	1.940	0.20	0.001457	8.302	0028
0.0236	1077	0.91	1.940	0.20	0.001476	8.302	0029
0.0239	1077	0.91	1.940	0.20	0.001494	8.302	0030
0.0229	1155	0.91	1.940	0.20	0.001276	8.303	0031
0.0226	1157	0.91	1.940	0.20	0.001259	8.303	0032
0.0223	1156	0.91	1.940	0.20	0.001243	8.303	0033
0.0223	1157	0.91	1.940	0.20	0.001243	8.303	0034
0.0223	1157	0.91	1.940	0.20	0.001243	8.303	0035
0.0207	1296	0.91	1.940	0.20	0.000911	8.304	0036
0.0207	1297	0.91	1.940	0.20	0.000911	8.304	0037
0.0211	1297	0.91	1.940	0.20	0.000929	8.304	0038
0.0211	1296	0.91	1.940	0.20	0.000929	8.304	0039
0.0211	1297	0.91	1.940	0.20	0.000929	8.304	0040

Table A-2
TEST 8 (PART I) DATA

K	Temperature (°C)	Density	O/M	Pu	Weight	Test Number	Number
0.0224	1295	0.91	1.950	0.20	0.001312	8.205	0001
0.0215	1283	0.91	1.950	0.20	0.001259	8.205	0002
0.0209	1284	0.91	1.950	0.20	0.001224	8.205	0003
0.0211	1282	0.91	1.950	0.20	0.001236	8.205	0004
0.0209	1284	0.91	1.950	0.20	0.001224	8.205	0005
0.0217	1175	0.91	1.950	0.20	0.001151	8.206	0006
0.0213	1172	0.91	1.950	0.20	0.001130	8.206	0007
0.0214	1171	0.91	1.950	0.20	0.001135	8.206	0008
0.0214	1172	0.91	1.950	0.20	0.001135	8.206	0009
0.0210	1172	0.91	1.950	0.20	0.001114	8.206	0010
0.0216	1046	0.91	1.950	0.20	0.001513	8.207	0011
0.0210	1044	0.91	1.950	0.20	0.001471	8.207	0012
0.0215	1044	0.91	1.950	0.20	0.001506	8.207	0013
0.0213	1042	0.91	1.950	0.20	0.001492	8.207	0014
0.0212	1042	0.91	1.950	0.20	0.001485	8.207	0015
0.0220	891	0.91	1.950	0.20	0.002110	8.208	0016
0.0224	891	0.91	1.950	0.20	0.002148	8.208	0017
0.0223	890	0.91	1.950	0.20	0.002138	8.208	0018
0.0222	890	0.91	1.950	0.20	0.002129	8.208	0019
0.0215	890	0.91	1.950	0.20	0.002062	8.208	0020
0.0246	1147	0.91	1.950	0.20	0.001361	8.306	0021
0.0246	1145	0.91	1.950	0.20	0.001361	8.306	0022
0.0253	1145	0.91	1.950	0.20	0.001399	8.306	0023
0.0249	1146	0.91	1.950	0.20	0.001377	8.306	0024
0.0249	1146	0.91	1.950	0.20	0.001377	8.306	0025
0.0253	1021	0.91	1.950	0.20	0.002104	8.307	0026
0.0274	1016	0.91	1.950	0.20	0.002279	8.307	0027
0.0274	1017	0.91	1.950	0.20	0.002279	8.307	0028
0.0270	1016	0.91	1.950	0.20	0.002245	8.307	0029
0.0274	1017	0.91	1.950	0.20	0.002279	8.307	0030
0.0296	868	0.91	1.950	0.20	0.003033	8.308	0031
0.0280	866	0.91	1.950	0.20	0.002869	8.308	0032
0.0285	865	0.91	1.950	0.20	0.002920	8.308	0033
0.0291	866	0.91	1.950	0.20	0.002892	8.308	0034
0.0285	864	0.91	1.950	0.20	0.002920	8.308	0035

Table A-3
TEST 8 (PART II) DATA

K	Temperature (°C)	Density	O/M	Pu	Weight	Test Number	Number
0.0229	1446	0.91	1.980	0.20	0.000856	8.209	0001
0.0227	1445	0.91	1.980	0.20	0.000849	8.209	0002
0.0227	1445	0.91	1.980	0.20	0.000849	8.209	0003
0.0224	1445	0.91	1.980	0.20	0.000838	8.209	0004
0.0227	1445	0.91	1.980	0.20	0.000849	8.209	0005
0.0220	1309	0.91	1.980	0.20	0.001001	8.210	0006
0.0219	1309	0.91	1.980	0.20	0.000996	8.210	0007
0.0222	1307	0.91	1.980	0.20	0.001010	8.210	0008
0.0222	1308	0.91	1.980	0.20	0.001010	8.210	0009
0.0218	1308	0.91	1.980	0.20	0.000992	8.210	0010
0.0236	1160	0.91	1.980	0.20	0.001380	8.211	0011
0.0242	1159	0.91	1.980	0.20	0.001415	8.211	0012
0.0240	1158	0.91	1.980	0.20	0.001404	8.211	0013
0.0239	1158	0.91	1.980	0.20	0.001398	8.211	0014
0.0242	1157	0.91	1.980	0.20	0.001415	8.211	0015
0.0259	1027	0.91	1.980	0.20	0.001953	8.212	0016
0.0259	1026	0.91	1.980	0.20	0.001953	8.212	0017
0.0261	1027	0.91	1.980	0.20	0.001968	8.212	0018
0.0259	1027	0.91	1.980	0.20	0.001953	8.212	0019
0.0259	1025	0.91	1.980	0.20	0.001953	8.212	0020
0.0260	875	0.91	1.980	0.20	0.002744	8.213	0021
0.0267	873	0.91	1.980	0.20	0.002818	8.213	0022
0.0266	872	0.91	1.980	0.20	0.002807	8.213	0023
0.0267	872	0.91	1.980	0.20	0.002818	8.213	0024
0.0267	872	0.91	1.980	0.20	0.002818	8.213	0025
0.0210	1440	0.91	1.970	0.20	0.000796	8.309	0026
0.0210	1440	0.91	1.980	0.20	0.000796	8.309	0027
0.0208	1439	0.91	1.980	0.20	0.000789	8.309	0028
0.0210	1439	0.91	1.980	0.20	0.000796	8.309	0029
0.0208	1439	0.91	1.980	0.20	0.000789	8.309	0030
0.0203	1301	0.91	1.980	0.20	0.000969	8.310	0031
0.0201	1303	0.91	1.980	0.20	0.000959	8.310	0032
0.0205	1301	0.91	1.980	0.20	0.000978	8.310	0033
0.0203	1300	0.91	1.980	0.20	0.000969	8.310	0034
0.0216	1158	0.91	1.980	0.20	0.001269	8.311	0035
0.0218	1158	0.91	1.980	0.20	0.001281	8.311	0036
0.0216	1158	0.91	1.980	0.20	0.001269	8.311	0037
0.0216	1157	0.91	1.980	0.20	0.001269	8.311	0038
0.0218	1158	0.91	1.980	0.20	0.001281	8.311	0039
0.0241	1030	0.91	1.980	0.20	0.001832	8.312	0040
0.0248	1029	0.91	1.980	0.20	0.001885	8.312	0041
0.0248	1030	0.91	1.980	0.20	0.001885	8.312	0042
0.0245	1029	0.91	1.980	0.20	0.001863	8.312	0043
0.0248	1029	0.91	1.980	0.20	0.001885	8.312	0044
0.0242	876	0.91	1.980	0.20	0.002583	8.313	0045
0.0234	874	0.91	1.980	0.20	0.002498	8.313	0046
0.0251	876	0.91	1.980	0.20	0.002679	8.313	0047
0.0246	876	0.91	1.980	0.20	0.002626	8.313	0048
0.0251	876	0.91	1.980	0.20	0.002679	8.313	0049

Table A-4
TEST 8 (PART II) DATA

K	Temperature (°C)	Density	O/M	Pu	Weight	Test Number	Number
0.0239	1318	0.91	2.000	0.20	0.001332	8.214	0001
0.0230	1320	0.91	2.000	0.20	0.001282	8.214	0002
0.0230	1319	0.91	2.000	0.20	0.001282	8.214	0003
0.0230	1318	0.91	2.000	0.20	0.001282	8.214	0004
0.0231	1319	0.91	2.000	0.20	0.001288	8.214	0005
0.0223	1175	0.91	2.000	0.20	0.001325	8.215	0006
0.0225	1174	0.91	2.000	0.20	0.001337	8.215	0007
0.0227	1173	0.91	2.000	0.20	0.001349	8.215	0008
0.0226	1173	0.91	2.000	0.20	0.001343	8.215	0009
0.0231	1173	0.91	2.000	0.20	0.001373	8.215	0010
0.0242	1044	0.91	2.000	0.20	0.001741	8.216	0011
0.0242	1044	0.91	2.000	0.20	0.001741	8.216	0012
0.0241	1045	0.91	2.000	0.20	0.001734	8.216	0013
0.0240	1045	0.91	2.000	0.20	0.001727	8.216	0014
0.0239	1046	0.91	2.000	0.20	0.001720	8.216	0015
0.0229	1290	0.91	2.000	0.20	0.001056	8.314	0016
0.0229	1291	0.91	2.000	0.20	0.001056	8.314	0017
0.0229	1290	0.91	2.000	0.20	0.001056	8.314	0018
0.0224	1289	0.91	2.000	0.20	0.001033	8.314	0019
0.0226	1291	0.91	2.000	0.20	0.001042	8.314	0020
0.0249	1148	0.91	2.000	0.20	0.001471	8.315	0021
0.0260	1147	0.91	2.000	0.20	0.001536	8.315	0022
0.0264	1147	0.91	2.000	0.20	0.001559	8.315	0023
0.0256	1147	0.91	2.000	0.20	0.001512	8.315	0024
0.0260	1146	0.91	2.000	0.20	0.001536	8.315	0025
0.0284	1018	0.91	2.000	0.20	0.002106	8.316	0026
0.0294	1019	0.91	2.000	0.20	0.002180	8.316	0027
0.0300	1020	0.91	2.000	0.20	0.002225	8.316	0028
0.0284	1019	0.91	2.000	0.20	0.002106	8.316	0029
0.0294	1019	0.91	2.000	0.20	0.002180	8.316	0030

Table A-5
TEST 8 (PART III) DATA

K	Temperature (°C)	Density	O/M	Pu	Weight	Test Number	Number
0.0199	880	0.91	1.950	0.20	0.000947	8.218	0001
0.0193	885	0.91	1.950	0.20	0.000919	8.218	0002
0.0196	884	0.91	1.950	0.20	0.000933	8.218	0003
0.0199	884	0.91	1.950	0.20	0.000947	8.218	0004
0.0196	880	0.91	1.950	0.20	0.000933	8.218	0005
0.0200	1119	0.91	1.950	0.20	0.000670	8.219	0006
0.0195	1122	0.91	1.950	0.20	0.000653	8.219	0007
0.0197	1117	0.91	1.950	0.20	0.000660	8.219	0008
0.0198	1118	0.91	1.950	0.20	0.000663	8.219	0009
0.0201	1119	0.91	1.950	0.20	0.000673	8.219	0010
0.0205	1240	0.91	1.950	0.20	0.000694	8.220	0011
0.0193	1242	0.91	1.950	0.20	0.000654	8.220	0012
0.0193	1241	0.91	1.950	0.20	0.000654	8.220	0013
0.0197	1241	0.91	1.950	0.20	0.000667	8.220	0014
0.0196	1240	0.91	1.950	0.20	0.000664	8.220	0015
0.0217	1446	0.91	1.950	0.20	0.000510	8.221	0016
0.0217	1448	0.91	1.950	0.20	0.000510	8.221	0017
0.0217	1451	0.91	1.950	0.20	0.000510	8.221	0018
0.0219	1449	0.91	1.950	0.20	0.000515	8.221	0019
0.0215	1449	0.91	1.950	0.20	0.000506	8.221	0020
0.0211	1582	0.91	1.950	0.20	0.000432	8.222	0021
0.0213	1581	0.91	1.950	0.20	0.000436	8.222	0022
0.0212	1584	0.91	1.950	0.20	0.000434	8.222	0023
0.0210	1582	0.91	1.950	0.20	0.000430	8.222	0024
0.0212	1582	0.91	1.950	0.20	0.000434	8.222	0025
0.0209	1795	0.91	1.950	0.20	0.000403	8.223	0026
0.0209	1797	0.91	1.950	0.20	0.000403	8.223	0027
0.0210	1795	0.91	1.950	0.20	0.000405	8.223	0028
0.0211	1795	0.91	1.950	0.20	0.000407	8.223	0029
0.0209	1797	0.91	1.950	0.20	0.000403	8.223	0030
0.0232	1984	0.91	1.950	0.20	0.000444	8.224	0031
0.0239	1986	0.91	1.950	0.20	0.000458	8.224	0032
0.0243	1984	0.91	1.950	0.20	0.000465	8.224	0033
0.0235	1986	0.91	1.950	0.20	0.000450	8.224	0034
0.0237	1986	0.91	1.950	0.20	0.000454	8.224	0035
0.0247	2195	0.91	1.950	0.20	0.000567	8.225	0036
0.0220	2198	0.91	1.950	0.20	0.000505	8.225	0037
0.0209	2196	0.91	1.950	0.20	0.000480	8.225	0038
0.0212	2199	0.91	1.950	0.20	0.000487	8.225	0039
0.0211	2198	0.91	1.950	0.20	0.000485	8.225	0040
0.0211	2198	0.91	1.950	0.20	0.000485	8.225	0041
0.0228	826	0.91	1.950	0.20	0.001159	8.318	0042
0.0226	827	0.91	1.950	0.20	0.001149	8.318	0043
0.0217	829	0.91	1.950	0.20	0.001103	8.318	0044
0.0219	827	0.91	1.950	0.20	0.001113	8.318	0045
0.0219	827	0.91	1.950	0.20	0.001113	8.318	0046
0.0191	1065	0.91	1.950	0.20	0.000628	8.319	0047

Table A-5 (continued)

K	Temperature (°C)	Density	O/M	Pu	Weight	Test Number	Number
0.0195	1065	0.91	1.950	0.20	0.000641	8.319	0048
0.0196	1063	0.91	1.950	0.20	0.000641	8.319	0049
0.0196	1065	0.91	1.950	0.20	0.000645	8.319	0050
0.0197	1065	0.91	1.950	0.20	0.000648	8.319	0051
0.0186	1187	0.91	1.950	0.20	0.000594	8.320	0052
0.0190	1188	0.91	1.950	0.20	0.000607	8.320	0053
0.0193	1185	0.91	1.950	0.20	0.000617	8.320	0054
0.0190	1183	0.91	1.950	0.20	0.000607	8.320	0055
0.0192	1187	0.91	1.950	0.20	0.000613	8.320	0056
0.0201	1402	0.91	1.950	0.20	0.000557	8.321	0057
0.0202	1397	0.91	1.950	0.20	0.000560	8.321	0058
0.0198	1399	0.91	1.950	0.20	0.000549	8.321	0059
0.0202	1397	0.91	1.950	0.20	0.000560	8.321	0060
0.0206	1399	0.91	1.950	0.20	0.000571	8.321	0061
0.0215	1529	0.91	1.950	0.20	0.000499	8.322	0062
0.0208	1531	0.91	1.950	0.20	0.000483	8.322	0063
0.0209	1532	0.91	1.950	0.20	0.000485	8.322	0064
0.0209	1532	0.91	1.950	0.20	0.000485	8.322	0065
0.0211	1531	0.91	1.950	0.20	0.000490	8.322	0066
0.0191	1743	0.91	1.950	0.20	0.000497	8.323	0067
0.0197	1739	0.91	1.950	0.20	0.000513	8.323	0068
0.0192	1738	0.91	1.950	0.20	0.000500	8.323	0069
0.0191	1738	0.91	1.950	0.20	0.000497	8.323	0070
0.0193	1742	0.91	1.950	0.20	0.000502	8.323	0071
0.0231	1940	0.91	1.950	0.20	0.000519	8.324	0072
0.0238	1937	0.91	1.950	0.20	0.000535	8.324	0073
0.0238	1937	0.91	1.950	0.20	0.000535	8.324	0074
0.0234	1939	0.91	1.950	0.20	0.000526	8.324	0075
0.0238	1940	0.91	1.950	0.20	0.000535	8.324	0076
0.0245	2127	0.91	1.950	0.20	0.000928	8.325	0077
0.0203	2141	0.91	1.950	0.20	0.000769	8.325	0078
0.0222	2139	0.91	1.950	0.20	0.000841	8.325	0079
0.0216	2146	0.91	1.950	0.20	0.000818	8.325	0080
0.0220	2143	0.91	1.950	0.20	0.000833	8.325	0081
0.0213	2145	0.91	1.950	0.20	0.000807	8.325	0082

Table A-6
TEST 10 DATA

K	Temperature (°C)	Density	O/M	Pu	Weight	Test Number	Number
0.0238	838	0.84	1.960	0.20	0.001592	10.201	0001
0.0225	842	0.84	1.960	0.20	0.001505	10.201	0002
0.0227	839	0.84	1.960	0.20	0.001518	10.201	0003
0.0226	839	0.84	1.960	0.20	0.001511	10.201	0004
0.0223	841	0.84	1.960	0.20	0.001491	10.201	0005
0.0207	1096	0.84	1.960	0.20	0.000870	10.202	0006
0.0206	1096	0.84	1.960	0.20	0.000866	10.202	0007
0.0206	1094	0.84	1.960	0.20	0.000866	10.202	0008
0.0205	1095	0.84	1.960	0.20	0.000862	10.202	0009
0.0205	1095	0.84	1.960	0.20	0.000862	10.202	0010
0.0199	1285	0.84	1.960	0.20	0.000560	10.203	0011
0.0194	1288	0.84	1.960	0.20	0.000546	10.203	0012
0.0200	1287	0.84	1.960	0.20	0.000563	10.203	0013
0.0199	1286	0.84	1.960	0.20	0.000560	10.203	0014
0.0198	1288	0.84	1.960	0.20	0.000557	10.203	0015
0.0202	1484	0.84	1.960	0.20	0.000432	10.204	0016
0.0204	1483	0.84	1.960	0.20	0.000437	10.204	0017
0.0201	1485	0.84	1.960	0.20	0.000430	10.204	0018
0.0201	1484	0.84	1.960	0.20	0.000430	10.204	0019
0.0202	1485	0.84	1.960	0.20	0.000432	10.204	0020
0.0197	1659	0.84	1.960	0.20	0.000926	10.205	0021
0.0196	1653	0.84	1.960	0.20	0.000921	10.205	0022
0.0200	1641	0.84	1.960	0.20	0.000940	10.205	0023
0.0211	1638	0.84	1.960	0.20	0.000991	10.205	0024
0.0204	1653	0.84	1.960	0.20	0.000958	10.205	0025
0.0197	1832	0.84	1.960	0.20	0.000343	10.206	0026
0.0198	1833	0.84	1.960	0.20	0.000345	10.206	0027
0.0203	1832	0.84	1.960	0.20	0.000353	10.206	0028
0.0199	1832	0.84	1.960	0.20	0.000347	10.206	0029
0.0198	1832	0.84	1.960	0.20	0.000345	10.206	0030
0.0228	2044	0.84	1.960	0.20	0.000423	10.207	0031
0.0226	2048	0.84	1.960	0.20	0.000419	10.207	0032
0.0225	2047	0.84	1.960	0.20	0.000418	10.207	0033
0.0225	2047	0.84	1.960	0.20	0.000418	10.207	0034
0.0228	2049	0.84	1.960	0.20	0.000423	10.207	0035
0.0234	2238	0.84	1.960	0.20	0.000404	10.208	0036
0.0236	2239	0.84	1.960	0.20	0.000408	10.208	0037
0.0231	2242	0.84	1.960	0.20	0.000399	10.208	0038
0.0236	2239	0.84	1.960	0.20	0.000408	10.208	0039
0.0231	2242	0.84	1.960	0.20	0.000399	10.208	0040
0.0277	803	0.84	1.960	0.20	0.002004	10.301	0041
0.0244	804	0.84	1.960	0.20	0.001765	10.301	0042
0.0257	804	0.84	1.960	0.20	0.001859	10.301	0043
0.0266	803	0.84	1.960	0.20	0.001925	10.301	0044
0.0255	803	0.84	1.960	0.20	0.001845	10.301	0045
0.0214	1049	0.84	1.960	0.20	0.000877	10.302	0046
0.0217	1048	0.84	1.960	0.20	0.000889	10.302	0047

Table A-6 (continued)

K	Temperature (°C)	Density	O/M	Pu	Weight	Test Number	Number
0.0217	1046	0.84	1.960	0.20	0.000889	10.302	0048
0.0214	1047	0.84	1.960	0.20	0.000877	10.302	0049
0.0219	1047	0.84	1.960	0.20	0.000897	10.302	0050
0.0195	1241	0.84	1.960	0.20	0.000534	10.303	0051
0.0193	1242	0.84	1.960	0.20	0.000528	10.303	0052
0.0196	1241	0.84	1.960	0.20	0.000537	10.303	0053
0.0195	1242	0.84	1.960	0.20	0.000534	10.303	0054
0.0193	1242	0.84	1.960	0.20	0.000528	10.303	0055
0.0202	1431	0.84	1.960	0.20	0.000485	10.304	0056
0.0199	1432	0.84	1.960	0.20	0.000477	10.304	0057
0.0198	1434	0.84	1.960	0.20	0.000475	10.304	0058
0.0199	1433	0.84	1.960	0.20	0.000477	10.304	0059
0.0199	1433	0.84	1.960	0.20	0.000477	10.304	0060
0.0197	1599	0.84	1.960	0.20	0.001719	10.305	0061
0.0196	1596	0.84	1.960	0.20	0.001710	10.305	0062
0.0223	1590	0.84	1.960	0.20	0.001945	10.305	0063
0.0239	1586	0.84	1.960	0.20	0.002085	10.305	0064
0.0211	1605	0.84	1.960	0.20	0.001841	10.305	0065
0.0209	1793	0.84	1.960	0.20	0.000397	10.306	0066
0.0207	1792	0.84	1.960	0.20	0.000394	10.306	0067
0.0208	1791	0.84	1.960	0.20	0.000395	10.306	0068
0.0207	1793	0.84	1.960	0.20	0.000394	10.306	0069
0.0209	1793	0.84	1.960	0.20	0.000397	10.306	0070
0.0237	2005	0.84	1.960	0.20	0.000470	10.307	0071
0.0229	2006	0.84	1.960	0.20	0.000454	10.307	0072
0.0237	2005	0.84	1.960	0.20	0.000470	10.307	0073
0.0237	2005	0.84	1.960	0.20	0.000470	10.307	0074
0.0235	2005	0.84	1.960	0.20	0.000466	10.307	0075
0.0248	2199	0.84	1.960	0.20	0.000725	10.308	0076
0.0233	2203	0.84	1.960	0.20	0.000681	10.308	0077
0.0233	2203	0.84	1.960	0.20	0.000681	10.308	0078
0.0233	2203	0.84	1.960	0.20	0.000681	10.308	0079
0.0233	2203	0.84	1.960	0.20	0.000681	10.308	0080

Table A-7
TEST 11 DATA

K	Temperature (°C)	Density	O/M	Pu	Weight	Test Number	Number
0.0265	813	0.855	1.965	0.20	0.002152	11.201	0001
0.0251	820	0.855	1.965	0.20	0.002038	11.201	0002
0.0256	819	0.855	1.965	0.20	0.002079	11.201	0003
0.0251	820	0.855	1.965	0.20	0.002038	11.201	0004
0.0261	817	0.855	1.965	0.20	0.002119	11.201	0005
0.0224	1085	0.855	1.965	0.20	0.000797	11.202	0006
0.0229	1085	0.855	1.965	0.20	0.000815	11.202	0007
0.0231	1084	0.855	1.965	0.20	0.000822	11.202	0008
0.0233	1084	0.855	1.965	0.20	0.000830	11.202	0009
0.0229	1086	0.855	1.965	0.20	0.000815	11.202	0010
0.0233	1296	0.855	1.965	0.20	0.000784	11.203	0011
0.0227	1294	0.855	1.965	0.20	0.000764	11.203	0012
0.0217	1297	0.855	1.965	0.20	0.000730	11.203	0013
0.0217	1296	0.855	1.965	0.20	0.000730	11.203	0014
0.0217	1296	0.855	1.965	0.20	0.000730	11.203	0015
0.0212	1448	0.855	1.965	0.20	0.000468	11.204	0016
0.0210	1451	0.855	1.965	0.20	0.000464	11.204	0017
0.0210	1450	0.855	1.965	0.20	0.000464	11.204	0018
0.0210	1451	0.855	1.965	0.20	0.000464	11.204	0019
0.0214	1450	0.855	1.965	0.20	0.000472	11.204	0020
0.0206	1655	0.855	1.965	0.20	0.000495	11.205	0021
0.0213	1654	0.855	1.965	0.20	0.000511	11.205	0022
0.0215	1655	0.855	1.965	0.20	0.000516	11.205	0023
0.0208	1654	0.855	1.965	0.20	0.000499	11.205	0024
0.0207	1656	0.855	1.965	0.20	0.000497	11.205	0025
0.0205	1825	0.855	1.965	0.20	0.000362	11.206	0026
0.0205	1825	0.855	1.965	0.20	0.000362	11.206	0027
0.0202	1827	0.855	1.965	0.20	0.000357	11.206	0028
0.0205	1825	0.855	1.965	0.20	0.000362	11.206	0029
0.0205	1825	0.855	1.965	0.20	0.000362	11.206	0030
0.0232	2060	0.855	1.965	0.20	0.000523	11.207	0031
0.0232	2060	0.855	1.965	0.20	0.000523	11.207	0032
0.0236	2061	0.855	1.965	0.20	0.000532	11.207	0033
0.0234	2060	0.855	1.965	0.20	0.000528	11.207	0034
0.0234	2058	0.855	1.965	0.20	0.000528	11.207	0035
0.0247	2228	0.855	1.965	0.20	0.000490	11.208	0036
0.0255	2230	0.855	1.965	0.20	0.000506	11.208	0037
0.0255	2230	0.855	1.965	0.20	0.000506	11.208	0038
0.0252	2229	0.855	1.965	0.20	0.000500	11.208	0039
0.0252	2229	0.855	1.965	0.20	0.000500	11.208	0040

Table A-8
TEST 11 DATA

K	Temperature (°C)	Density	O/M	Pu	Weight	Test Number	Number
0.0256	810	0.869	1.965	0.20	0.001719	11.301	0001
0.0254	813	0.869	1.965	0.20	0.001706	11.301	0002
0.0253	813	0.869	1.965	0.20	0.001699	11.301	0003
0.0262	813	0.869	1.965	0.20	0.001759	11.301	0004
0.0244	814	0.869	1.965	0.20	0.001639	11.301	0005
0.0212	1089	0.869	1.965	0.20	0.000716	11.302	0006
0.0214	1090	0.869	1.965	0.20	0.000723	11.302	0007
0.0211	1088	0.869	1.965	0.20	0.000713	11.302	0008
0.0214	1090	0.869	1.965	0.20	0.000723	11.302	0009
0.0212	1089	0.869	1.965	0.20	0.000716	11.302	0010
0.0200	1312	0.869	1.965	0.20	0.000503	11.303	0011
0.0198	1311	0.869	1.965	0.20	0.000498	11.303	0012
0.0202	1313	0.869	1.965	0.20	0.000509	11.303	0013
0.0202	1313	0.869	1.965	0.20	0.000509	11.303	0014
0.0201	1313	0.869	1.965	0.20	0.000506	11.303	0015
0.0195	1462	0.869	1.965	0.20	0.000386	11.304	0016
0.0194	1461	0.869	1.965	0.20	0.000384	11.304	0017
0.0197	1462	0.869	1.965	0.20	0.000390	11.304	0018
0.0195	1462	0.869	1.965	0.20	0.000386	11.304	0019
0.0195	1461	0.869	1.965	0.20	0.000386	11.304	0020
0.0197	1669	0.869	1.965	0.20	0.000405	11.305	0021
0.0201	1669	0.869	1.965	0.20	0.000414	11.305	0022
0.0196	1671	0.869	1.965	0.20	0.000403	11.305	0023
0.0198	1672	0.869	1.965	0.20	0.000407	11.305	0024
0.0200	1671	0.869	1.965	0.20	0.000411	11.305	0025
0.0199	1848	0.869	1.965	0.20	0.000342	11.306	0026
0.0200	1849	0.869	1.965	0.20	0.000344	11.306	0027
0.0197	1848	0.869	1.965	0.20	0.000339	11.306	0028
0.0200	1849	0.869	1.965	0.20	0.000344	11.306	0029
0.0201	1850	0.869	1.965	0.20	0.000346	11.306	0030
0.0222	2078	0.869	1.965	0.20	0.000300	11.307	0031
0.0222	2078	0.869	1.965	0.20	0.000300	11.307	0032
0.0222	2078	0.869	1.965	0.20	0.000300	11.307	0033
0.0221	2078	0.869	1.965	0.20	0.000299	11.307	0034
0.0223	2079	0.869	1.965	0.20	0.000301	11.307	0035
0.0221	2244	0.869	1.965	0.20	0.000564	11.308	0036
0.0210	2250	0.869	1.965	0.20	0.000536	11.308	0037
0.0207	2247	0.869	1.965	0.20	0.000528	11.308	0038
0.0212	2250	0.869	1.965	0.20	0.000541	11.308	0039
0.0217	2249	0.869	1.965	0.20	0.000554	11.308	0040

Table A-9
TEST 13 DATA

K	Temperature (°C)	Density	O/M	Pu	Test Number	Number
0.0272	959	0.91	1.986	0.10	13.301	0001
0.0248	974	0.91	1.986	0.10	13.301	0002
0.0235	982	0.91	1.986	0.10	13.301	0003
0.0234	985	0.91	1.986	0.10	13.301	0004
0.0236	984	0.91	1.986	0.10	13.301	0005
0.0210	1163	0.91	1.986	0.10	13.302	0006
0.0212	1161	0.91	1.986	0.10	13.302	0007
0.0209	1163	0.91	1.986	0.10	13.302	0008
0.0213	1162	0.91	1.986	0.10	13.302	0009
0.0212	1161	0.91	1.986	0.10	13.302	0010
0.0224	1324	0.91	1.986	0.10	13.303	0011
0.0217	1327	0.91	1.986	0.10	13.303	0012
0.0215	1329	0.91	1.986	0.10	13.303	0013
0.0217	1328	0.91	1.986	0.10	13.303	0014
0.0216	1328	0.91	1.986	0.10	13.303	0015
0.0224	1493	0.91	1.986	0.10	13.304	0016
0.0223	1493	0.91	1.986	0.10	13.304	0017
0.0226	1487	0.91	1.986	0.10	13.304	0018
0.0231	1487	0.91	1.986	0.10	13.304	0019
0.0222	1487	0.91	1.986	0.10	13.304	0020
0.0233	1667	0.91	1.986	0.10	13.305	0021
0.0233	1670	0.91	1.986	0.10	13.305	0022
0.0232	1668	0.91	1.986	0.10	13.305	0023
0.0214	1663	0.91	1.986	0.10	13.305	0024
0.0214	1663	0.91	1.986	0.10	13.305	0025
0.0251	1898	0.91	1.986	0.10	13.306	0026
0.0255	1898	0.91	1.986	0.10	13.306	0027
0.0256	1895	0.91	1.986	0.10	13.306	0028
0.0248	1897	0.91	1.986	0.10	13.306	0029
0.0253	1898	0.91	1.986	0.10	13.306	0030
0.0235	2064	0.91	1.986	0.10	13.307	0031
0.0235	2067	0.91	1.986	0.10	13.307	0032
0.0236	2065	0.91	1.986	0.10	13.307	0033
0.0236	2065	0.91	1.986	0.10	13.307	0034
0.0238	2066	0.91	1.986	0.10	13.307	0035
0.0236	2266	0.91	1.986	0.10	13.308	0036
0.0250	2268	0.91	1.986	0.10	13.308	0037
0.0255	2264	0.91	1.986	0.10	13.308	0038
0.0251	2267	0.91	1.986	0.10	13.308	0039
0.0248	2266	0.91	1.986	0.10	13.308	0040

Table A-10
TEST 3 DATA

K	Temperature (°C)	Density	O/M	Pu	Test Number	Number
0.0240	901	0.93	1.950	0.30	3.101	0001
0.0235	1106	0.93	1.950	0.30	3.102	0002
0.0237	1077	0.93	1.950	0.30	3.102	0003
0.0217	1302	0.93	1.950	0.30	3.103	0004
0.0251	1267	0.93	1.950	0.30	3.103	0005
0.0201	1584	0.93	1.950	0.30	3.108	0006
0.0207	1758	0.93	1.950	0.30	3.109	0007
0.0209	1940	0.93	1.950	0.30	3.110	0008
0.0242	2125	0.93	1.950	0.30	3.111	0009
0.0237	2279	0.93	1.950	0.30	3.112	0010
0.0240	919	0.93	1.950	0.30	3.201	0011
0.0213	1123	0.93	1.950	0.30	3.202	0012
0.0209	1330	0.93	1.950	0.30	3.203	0013
0.0205	1573	0.93	1.950	0.30	3.204	0014
0.0205	1619	0.93	1.950	0.30	3.205	0015
0.0205	1763	0.93	1.950	0.30	3.206	0016
0.0205	1389	0.93	1.950	0.30	3.207	0017
0.0203	1617	0.93	1.950	0.30	3.208	0018
0.0207	1793	0.93	1.950	0.30	3.209	0019
0.0212	1796	0.93	1.950	0.30	3.210	0020
0.0231	2167	0.93	1.950	0.30	3.211	0021

Table A-11
TEST 12 DATA

K	Temperature (°C)	Density	O/M	Pu	Test Number	Number
0.0225	880	0.976	1.860	1.00	12.201	0001
0.0205	875	0.976	1.860	1.00	12.201	0002
0.0201	870	0.976	1.860	1.00	12.201	0003
0.0206	873	0.976	1.860	1.00	12.201	0004
0.0208	876	0.976	1.860	1.00	12.201	0005
0.0207	1121	0.976	1.860	1.00	12.202	0006
0.0204	1121	0.976	1.860	1.00	12.202	0007
0.0208	1121	0.976	1.860	1.00	12.202	0008
0.0199	1121	0.976	1.860	1.00	12.202	0009
0.0203	1122	0.976	1.860	1.00	12.202	0010
0.0205	1261	0.976	1.860	1.00	12.203	0011
0.0210	1259	0.976	1.860	1.00	12.203	0012
0.0208	1258	0.976	1.860	1.00	12.203	0013
0.0207	1259	0.976	1.860	1.00	12.203	0014
0.0210	1260	0.976	1.860	1.00	12.203	0015
0.0206	1437	0.976	1.860	1.00	12.204	0016
0.0211	1433	0.976	1.860	1.00	12.204	0017
0.0207	1434	0.976	1.860	1.00	12.204	0018
0.0209	1433	0.976	1.860	1.00	12.204	0019
0.0208	1434	0.976	1.860	1.00	12.204	0020
0.0236	1604	0.976	1.860	1.00	12.205	0021
0.0229	1615	0.976	1.860	1.00	12.205	0022
0.0231	1597	0.976	1.860	1.00	12.205	0023
0.0225	1614	0.976	1.860	1.00	12.205	0024
0.0214	1612	0.976	1.860	1.00	12.205	0025
0.0191	1797	0.976	1.860	1.00	12.206	0026
0.0225	1789	0.976	1.860	1.00	12.206	0027
0.0244	1773	0.976	1.860	1.00	12.206	0028
0.0224	1776	0.976	1.860	1.00	12.206	0029
0.0219	1775	0.976	1.860	1.00	12.206	0030
0.0197	940	0.976	1.860	1.00	12.301	0031
0.0191	934	0.976	1.860	1.00	12.301	0032
0.0190	935	0.976	1.860	1.00	12.301	0033
0.0191	936	0.976	1.860	1.00	12.301	0034
0.0185	935	0.976	1.860	1.00	12.301	0035
0.0197	1211	0.976	1.860	1.00	12.302	0036
0.0197	1209	0.976	1.860	1.00	12.302	0037
0.0196	1210	0.976	1.860	1.00	12.302	0038
0.0195	1206	0.976	1.860	1.00	12.302	0039
0.0201	1209	0.976	1.860	1.00	12.302	0040
0.0200	1357	0.976	1.860	1.00	12.303	0041
0.0199	1354	0.976	1.860	1.00	12.303	0042
0.0201	1353	0.976	1.860	1.00	12.303	0043
0.0197	1354	0.976	1.860	1.00	12.303	0044
0.0200	1356	0.976	1.860	1.00	12.303	0045
0.0220	1528	0.976	1.860	1.00	12.304	0046
0.0217	1526	0.976	1.860	1.00	12.304	0047

Table A-11 (Continued)

K	Temperature (°C)	Density	O/M	Pu	Test Number	Number
0.0221	1527	0.976	1.860	1.00	12.304	0048
0.0219	1527	0.976	1.860	1.00	12.304	0049
0.0221	1528	0.976	1.860	1.00	12.304	0050
0.0239	1720	0.976	1.860	1.00	12.305	0051
0.0233	1719	0.976	1.860	1.00	12.305	0052
0.0231	1719	0.976	1.860	1.00	12.305	0053
0.0234	1720	0.976	1.860	1.00	12.305	0054
0.0233	1718	0.976	1.860	1.00	12.305	0055
0.0250	1914	0.976	1.860	1.00	12.306	0056
0.0292	1918	0.976	1.860	1.00	12.306	0057
0.0221	1892	0.976	1.860	1.00	12.306	0058
0.0236	1887	0.976	1.860	1.00	12.306	0059
0.0232	1886	0.976	1.860	1.00	12.306	0060

Table A-12
TEST 7 AND TEST 13 DATA

K	Temperature (°C)	Density	O/M	Pu	Test Number	Number
0.0260	891	0.976	2.000	0	7.101	0001
0.0264	887	0.976	2.000	0	7.101	0002
0.0288	885	0.976	2.000	0	7.101	0003
0.0285	987	0.976	2.000	0	7.102	0004
0.0256	991	0.976	2.000	0	7.102	0005
0.0257	992	0.976	2.000	0	7.102	0006
0.0254	992	0.976	2.000	0	7.102	0007
0.0253	992	0.976	2.000	0	7.102	0008
0.0250	1196	0.976	2.000	0	7.103	0009
0.0234	1193	0.976	2.000	0	7.103	0010
0.0242	1191	0.976	2.000	0	7.103	0011
0.0232	1191	0.976	2.000	0	7.103	0012
0.0232	1191	0.976	2.000	0	7.103	0013
0.0243	1397	0.976	2.000	0	7.104	0014
0.0250	1394	0.976	2.000	0	7.104	0015
0.0243	1392	0.976	2.000	0	7.104	0016
0.0246	1392	0.976	2.000	0	7.104	0017
0.0246	1392	0.976	2.000	0	7.104	0018
0.0229	1567	0.976	2.000	0	7.105	0019
0.0226	1568	0.976	2.000	0	7.105	0020
0.0227	1568	0.976	2.000	0	7.105	0021
0.0243	1568	0.976	2.000	0	7.105	0022
0.0234	1565	0.976	2.000	0	7.105	0023
0.0209	1732	0.976	2.000	0	7.106	0024
0.0216	1730	0.976	2.000	0	7.106	0025
0.0211	1731	0.976	2.000	0	7.106	0026
0.0217	1729	0.976	2.000	0	7.106	0027
0.0217	1730	0.976	2.000	0	7.106	0028
0.0291	879	0.976	2.000	0	7.201	0029
0.0305	878	0.976	2.000	0	7.201	0030
0.0354	878	0.976	2.000	0	7.201	0031
0.0331	980	0.976	2.000	0	7.202	0032
0.0279	979	0.976	2.000	0	7.202	0033
0.0303	979	0.976	2.000	0	7.202	0034
0.0297	978	0.976	2.000	0	7.202	0035
0.0279	979	0.976	2.000	0	7.202	0036
0.0248	1178	0.976	2.000	0	7.203	0037
0.0278	1179	0.976	2.000	0	7.203	0038
0.0268	1178	0.976	2.000	0	7.203	0039
0.0253	1172	0.976	2.000	0	7.203	0040
0.0261	1174	0.976	2.000	0	7.203	0041
0.0244	1395	0.976	2.000	0	7.204	0042
0.0223	1395	0.976	2.000	0	7.204	0043
0.0233	1394	0.976	2.000	0	7.204	0044
0.0227	1392	0.976	2.000	0	7.204	0045
0.0224	1392	0.976	2.000	0	7.204	0046
0.0221	1567	0.976	2.000	0	7.205	0047

Table A-12 (Continued)

K	Temperature (°C)	Density	O/M	Pu	Test Number	Number
0.0214	1567	0.976	2.000	0	7.205	0048
0.0214	1568	0.976	2.000	0	7.205	0049
0.0214	1567	0.976	2.000	0	7.205	0050
0.0212	1569	0.976	2.000	0	7.205	0051
0.0172	1739	0.976	2.000	0	7.206	0052
0.0177	1737	0.976	2.000	0	7.206	0053
0.0175	1738	0.976	2.000	0	7.206	0054
0.0177	1736	0.976	2.000	0	7.206	0055
0.0175	1738	0.976	2.000	0	7.206	0056
0.0336	892	0.976	2.000	0	7.301	0057
0.0349	888	0.976	2.000	0	7.301	0058
0.0388	888	0.976	2.000	0	7.301	0059
0.0340	994	0.976	2.000	0	7.302	0060
0.0344	994	0.976	2.000	0	7.302	0061
0.0343	994	0.976	2.000	0	7.302	0062
0.0345	994	0.976	2.000	0	7.302	0063
0.0339	994	0.976	2.000	0	7.302	0064
0.0281	1204	0.976	2.000	0	7.303	0065
0.0289	1202	0.976	2.000	0	7.303	0066
0.0285	1202	0.976	2.000	0	7.303	0067
0.0289	1189	0.976	2.000	0	7.303	0068
0.0286	1200	0.976	2.000	0	7.303	0069
0.0251	1419	0.976	2.000	0	7.304	0070
0.0246	1420	0.976	2.000	0	7.304	0071
0.0246	1419	0.976	2.000	0	7.304	0072
0.0251	1417	0.976	2.000	0	7.304	0073
0.0248	1416	0.976	2.000	0	7.304	0074
0.0234	1593	0.976	2.000	0	7.305	0075
0.0239	1595	0.976	2.000	0	7.305	0076
0.0236	1595	0.976	2.000	0	7.305	0077
0.0241	1593	0.976	2.000	0	7.305	0078
0.0236	1595	0.976	2.000	0	7.305	0079
0.0222	1759	0.976	2.000	0	7.306	0080
0.0221	1759	0.976	2.000	0	7.306	0081
0.0222	1758	0.976	2.000	0	7.306	0082
0.0220	1758	0.976	2.000	0	7.306	0083
0.0221	1759	0.976	2.000	0	7.306	0084
0.0289	1124	0.976	2.000	0	13.202	0085
0.0277	1124	0.976	2.000	0	13.202	0086
0.0288	1124	0.976	2.000	0	13.202	0087
0.0279	1125	0.976	2.000	0	13.202	0088
0.0281	1125	0.976	2.000	0	13.202	0089
0.0259	1281	0.976	2.000	0	13.203	0090
0.0267	1288	0.976	2.000	0	13.203	0091
0.0268	1290	0.976	2.000	0	13.203	0092
0.0283	1288	0.976	2.000	0	13.203	0093
0.0278	1289	0.976	2.000	0	13.203	0094
0.0248	1450	0.976	2.000	0	13.204	0095

Table A-12 (Continued)

K	Temperature (°C)	Density	O/M	Pu	Test Number	Number
0.0259	1449	0.976	2.000	0	13.204	0096
0.0266	1442	0.976	2.000	0	13.204	0097
0.0269	1443	0.976	2.000	0	13.204	0098
0.0264	1444	0.976	2.000	0	13.204	0099
0.0269	1626	0.976	2.000	0	13.205	0100
0.0265	1627	0.976	2.000	0	13.205	0101
0.0252	1624	0.976	2.000	0	13.205	0102
0.0238	1630	0.976	2.000	0	13.205	0103
0.0238	1629	0.976	2.000	0	13.205	0104
0.0258	1864	0.976	2.000	0	13.206	0105
0.0262	1865	0.976	2.000	0	13.206	0106
0.0261	1863	0.976	2.000	0	13.206	0107
0.0260	1864	0.976	2.000	0	13.206	0108
0.0261	1863	0.976	2.000	0	13.206	0109
0.0265	2039	0.976	2.000	0	13.207	0110
0.0282	2038	0.976	2.000	0	13.207	0111
0.0273	2038	0.976	2.000	0	13.207	0112
0.0271	2037	0.976	2.000	0	13.207	0113
0.0276	2037	0.976	2.000	0	13.207	0114
0.0276	2232	0.976	2.000	0	13.208	0115
0.0289	2234	0.976	2.000	0	13.208	0116
0.0254	2241	0.976	2.000	0	13.208	0117
0.0263	2242	0.976	2.000	0	13.208	0118
0.0247	2242	0.976	2.000	0	13.208	0119

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Figure A-1. Test 8 (Part I)

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Figure A-2. Test 8 (Part I)

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Figure A-3. Test 8 (Part II)

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Figure A-4. Test 8 (Part II)

Figure A-5. Test 8 (Part III)

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Figure A-6. Test 10

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Figure A-7. Test 11

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Figure A-8. Test 11

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Figure A-9. Test 13

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Figure A-10. Test 3

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Figure A-11. Test 12

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Figure A-12. Test 7 and Test 13

APPENDIX B. STATISTICAL ANALYSIS RESULTS

The results of the statistical analysis used to determine the empirical equation for the thermal conductivity of $(U_{0.8}Pu_{0.2})O_{2-x}$ are given in this appendix. As indicated, only the 20% Pu/(Pu+U) data were used to determine the equation. This represented data from Tests 8(I), 8(II), 8(III), 10 and 11 (see Appendix A) for a total of 396 data points which are indicated by "sample number" here. The "independent variable" is temperature ($^{\circ}C$); the "dependent variable" is thermal conductivity ($W/cm^{\circ}C$); the "residual" is the "observed" minus the "predicted" value of the dependent variable; the "percent deviation" is based upon the predicted value of the dependent variable and the "90% confidence limits" are based upon the predicted value of the dependent variable.

The term "predicted" is the value determined by the empirical equation. The "observed" value is the measured one.

SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE		RESIDUAL	PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			
		OBSERVED	PREDICTED			LOWER	UPPER	WIDTH	% WIDTH
376	1461.0	0.19500E-01	0.20488E-01	-0.98838E-03	-4.82	1.84728E-02	2.25040E-02	4.03120E-03	19.68
377	1669.0	0.19700E-01	0.20710E-01	-0.10100E-02	-4.88	1.88194E-02	2.26005E-02	3.78112E-03	18.26
378	1669.0	0.20100E-01	0.20710E-01	-0.60998E-03	-2.95	1.88298E-02	2.25902E-02	3.76040E-03	18.16
379	1671.0	0.19600E-01	0.20714E-01	-0.11144E-02	-5.38	1.88234E-02	2.26054E-02	3.78205E-03	18.26
380	1672.0	0.19800E-01	0.20717E-01	-0.91662E-03	-4.42	1.88312E-02	2.26020E-02	3.77084E-03	18.20
381	1671.0	0.20000E-01	0.20714E-01	-0.71440E-03	-3.45	1.88326E-02	2.25962E-02	3.76351E-03	18.17
382	1848.0	0.19900E-01	0.21263E-01	-0.13633E-02	-6.41	1.94186E-02	2.31079E-02	3.68928E-03	17.35
383	1849.0	0.20000E-01	0.21267E-01	-0.12672E-02	-5.96	1.94252E-02	2.31093E-02	3.68405E-03	17.32
384	1848.0	0.19700E-01	0.21263E-01	-0.15633E-02	-7.35	1.94146E-02	2.31120E-02	3.69741E-03	17.39
385	1849.0	0.20000E-01	0.21267E-01	-0.12672E-02	-5.96	1.94252E-02	2.31093E-02	3.68405E-03	17.32
386	1850.0	0.20100E-01	0.21271E-01	-0.11712E-02	-5.51	1.94318E-02	2.31107E-02	3.67890E-03	17.30
387	2078.0	0.22200E-01	0.22421E-01	-0.22115E-03	-0.99	1.98907E-02	2.49516E-02	5.06085E-03	22.57
388	2078.0	0.22200E-01	0.22421E-01	-0.22115E-03	-0.99	1.98907E-02	2.49516E-02	5.06085E-03	22.57
389	2078.0	0.22200E-01	0.22421E-01	-0.22115E-03	-0.99	1.98907E-02	2.49516E-02	5.06085E-03	22.57
390	2078.0	0.22100E-01	0.22421E-01	-0.32115E-03	-1.43	1.98886E-02	2.49537E-02	5.06507E-03	22.59
391	2079.0	0.22300E-01	0.22427E-01	-0.12725E-03	-0.57	1.98931E-02	2.49614E-02	5.06823E-03	22.60
392	2244.0	0.22100E-01	0.23561E-01	-0.14607E-02	-6.20	2.02867E-02	2.68346E-02	6.54793E-03	27.79
393	2250.0	0.21000E-01	0.23607E-01	-0.26066E-02	-11.04	2.02398E-02	2.69734E-02	6.73365E-03	28.52
394	2247.0	0.20700E-01	0.23584E-01	-0.28836E-02	-12.23	2.02297E-02	2.69375E-02	6.70774E-03	28.44
395	2250.0	0.21200E-01	0.23607E-01	-0.24066E-02	-10.19	2.02476E-02	2.69656E-02	6.71804E-03	28.46
396	2249.0	0.21700E-01	0.23599E-01	-0.18989E-02	-8.05	2.02683E-02	2.69296E-02	6.66135E-03	28.23

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SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE		RESIDUAL	PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			
		OBSERVED	PREDICTED			LOWER	UPPER	WIDTH	% WIDTH
351	2058.0	0.23400E-01	0.22292E-01	0.11078E-02	4.97	2.01862E-02	2.43981E-02	4.21195E-03	18.89
352	2228.0	0.24700E-01	0.23432E-01	0.12685E-02	5.41	2.02185E-02	2.66445E-02	6.42603E-03	27.42
353	2230.0	0.25500E-01	0.23447E-01	0.20535E-02	8.76	2.02430E-02	2.66500E-02	6.40700E-03	27.33
354	2230.0	0.25500E-01	0.23447E-01	0.20535E-02	8.76	2.02430E-02	2.66500E-02	6.40700E-03	27.33
355	2229.0	0.25200E-01	0.23439E-01	0.17610E-02	7.51	2.02341E-02	2.66440E-02	6.40987E-03	27.35
356	2229.0	0.25200E-01	0.23439E-01	0.17610E-02	7.51	2.02341E-02	2.66440E-02	6.40987E-03	27.35
357	810.00	0.25600E-01	0.24993E-01	0.60734E-03	2.43	2.16154E-02	2.83699E-02	6.75445E-03	27.03
358	813.00	0.25400E-01	0.24934E-01	0.46563E-03	1.87	2.15918E-02	2.82769E-02	6.68516E-03	26.81
359	813.00	0.25300E-01	0.24934E-01	0.36563E-03	1.47	2.15883E-02	2.82804E-02	6.69204E-03	26.84
360	813.00	0.26200E-01	0.24934E-01	0.12656E-02	5.08	2.16173E-02	2.82515E-02	6.63423E-03	26.61
361	814.00	0.24400E-01	0.24915E-01	-0.51509E-03	-2.07	2.15526E-02	2.82776E-02	6.72505E-03	26.99
362	1089.0	0.21200E-01	0.21623E-01	-0.42268E-03	-1.95	1.99259E-02	2.33194E-02	3.39353E-03	15.69
363	1090.0	0.21400E-01	0.21616E-01	-0.21588E-03	-1.00	1.99257E-02	2.33061E-02	3.38043E-03	15.64
364	1088.0	0.21100E-01	0.21630E-01	-0.52950E-03	-2.45	1.99285E-02	2.33305E-02	3.40204E-03	15.73
365	1090.0	0.21400E-01	0.21616E-01	-0.21588E-03	-1.00	1.99257E-02	2.33061E-02	3.38043E-03	15.64
366	1089.0	0.21200E-01	0.21623E-01	-0.42268E-03	-1.95	1.99259E-02	2.33194E-02	3.39353E-03	15.69
367	1312.0	0.20000E-01	0.20660E-01	-0.65960E-03	-3.19	1.88506E-02	2.24686E-02	3.61800E-03	17.51
368	1311.0	0.19800E-01	0.20662E-01	-0.86184E-03	-4.17	1.88491E-02	2.24746E-02	3.62547E-03	17.55
369	1313.0	0.20200E-01	0.20657E-01	-0.45737E-03	-2.21	1.88529E-02	2.24618E-02	3.60886E-03	17.47
370	1313.0	0.20200E-01	0.20657E-01	-0.45737E-03	-2.21	1.88529E-02	2.24618E-02	3.60886E-03	17.47
371	1313.0	0.20100E-01	0.20657E-01	-0.55737E-03	-2.70	1.88503E-02	2.24645E-02	3.61420E-03	17.50
372	1462.0	0.19500E-01	0.20488E-01	-0.98824E-03	-4.82	1.84725E-02	2.25040E-02	4.03147E-03	19.68
373	1461.0	0.19400E-01	0.20488E-01	-0.10884E-02	-5.31	1.84702E-02	2.25066E-02	4.03644E-03	19.70
374	1462.0	0.19700E-01	0.20488E-01	-0.78824E-03	-3.85	1.84777E-02	2.24988E-02	4.02109E-03	19.63
375	1462.0	0.19500E-01	0.20488E-01	-0.98824E-03	-4.82	1.84725E-02	2.25040E-02	4.03147E-03	19.68

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SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE		RESIDUAL	PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			% WIDTH
		OBSERVED	PREDICTED			LOWER	UPPER	WIDTH	
326	1086.0	0.22900E-01	0.21626E-01	0.12736E-02	5.89	1.99466E-02	2.33062E-02	3.35959E-03	15.53
327	1296.0	0.23300E-01	0.20683E-01	0.26167E-02	12.65	1.89608E-02	2.24059E-02	3.44511E-03	16.66
328	1294.0	0.22700E-01	0.20688E-01	0.20117E-02	9.72	1.89564E-02	2.24203E-02	3.46391E-03	16.74
329	1297.0	0.21700E-01	0.20681E-01	0.10191E-02	4.93	1.89264E-02	2.24353E-02	3.50890E-03	16.97
330	1296.0	0.21700E-01	0.20683E-01	0.10167E-02	4.92	1.89298E-02	2.24369E-02	3.50713E-03	16.96
331	1296.0	0.21700E-01	0.20683E-01	0.10167E-02	4.92	1.89298E-02	2.24369E-02	3.50713E-03	16.96
332	1448.0	0.21200E-01	0.20479E-01	0.72128E-03	3.52	1.84160E-02	2.25415E-02	4.12553E-03	20.15
333	1451.0	0.21000E-01	0.20478E-01	0.52212E-03	2.55	1.84100E-02	2.25457E-02	4.13569E-03	20.20
334	1450.0	0.21000E-01	0.20478E-01	0.52185E-03	2.55	1.84105E-02	2.25458E-02	4.13527E-03	20.19
335	1451.0	0.21000E-01	0.20478E-01	0.52212E-03	2.55	1.84100E-02	2.25457E-02	4.13569E-03	20.20
336	1450.0	0.21400E-01	0.20478E-01	0.92185E-03	4.50	1.84193E-02	2.25370E-02	4.11764E-03	20.11
337	1655.0	0.20600E-01	0.20669E-01	-0.69190E-04	-0.33	1.87267E-02	2.26117E-02	3.88493E-03	18.80
338	1654.0	0.21300E-01	0.20667E-01	0.63286E-03	3.06	1.87391E-02	2.25952E-02	3.85609E-03	18.66
339	1655.0	0.21500E-01	0.20669E-01	0.83081E-03	4.02	1.87468E-02	2.25916E-02	3.84478E-03	18.60
340	1654.0	0.20800E-01	0.20667E-01	0.13287E-03	0.64	1.87276E-02	2.26067E-02	3.87906E-03	18.77
341	1656.0	0.20700E-01	0.20671E-01	0.28745E-04	0.14	1.87317E-02	2.26108E-02	3.87906E-03	18.77
342	1825.0	0.20500E-01	0.21165E-01	-0.66471E-03	-3.14	1.92374E-02	2.30920E-02	3.85464E-03	18.21
343	1825.0	0.20500E-01	0.21165E-01	-0.66471E-03	-3.14	1.92374E-02	2.30920E-02	3.85464E-03	18.21
344	1827.0	0.20200E-01	0.21172E-01	-0.97222E-03	-4.59	1.92393E-02	2.31051E-02	3.86579E-03	18.26
345	1825.0	0.20500E-01	0.21165E-01	-0.66471E-03	-3.14	1.92374E-02	2.30920E-02	3.85464E-03	18.21
346	1825.0	0.20500E-01	0.21165E-01	-0.66471E-03	-3.14	1.92374E-02	2.30920E-02	3.85464E-03	18.21
347	2060.0	0.23200E-01	0.22304E-01	0.89599E-03	4.02	2.01846E-02	2.44234E-02	4.23882E-03	19.00
348	2060.0	0.23200E-01	0.22304E-01	0.89599E-03	4.02	2.01846E-02	2.44234E-02	4.23882E-03	19.00
349	2061.0	0.23600E-01	0.22310E-01	0.12900E-02	5.78	2.01953E-02	2.44246E-02	4.22923E-03	18.96
350	2060.0	0.23400E-01	0.22304E-01	0.10960E-02	4.91	2.01896E-02	2.44184E-02	4.22875E-03	18.96

SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE		RESIDUAL	PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			
		OBSERVED	PREDICTED			LOWER	UPPER	WIDTH	% WIDTH
301	1605.0	0.21100E-01	0.20451E-01	0.64913E-03	3.17	1.89297E-02	2.19721E-02	3.04242E-03	14.88
302	1793.0	0.20900E-01	0.20946E-01	-0.45708E-04	-0.22	1.89370E-02	2.29544E-02	4.01746E-03	19.18
303	1792.0	0.20700E-01	0.20942E-01	-0.24216E-03	-1.16	1.89285E-02	2.29558E-02	4.02731E-03	19.23
304	1791.0	0.20800E-01	0.20939E-01	-0.13863E-03	-0.66	1.89251E-02	2.29521E-02	4.02700E-03	19.23
305	1793.0	0.20700E-01	0.20946E-01	-0.24571E-03	-1.17	1.89332E-02	2.29583E-02	4.02509E-03	19.22
306	1793.0	0.20900E-01	0.20946E-01	-0.45708E-04	-0.22	1.89370E-02	2.29544E-02	4.01746E-03	19.18
307	2005.0	0.23700E-01	0.21907E-01	0.17928E-02	8.18	1.99094E-02	2.39050E-02	3.99568E-03	18.24
308	2006.0	0.22900E-01	0.21913E-01	0.98729E-03	4.51	1.98949E-02	2.39305E-02	4.03552E-03	18.42
309	2005.0	0.23700E-01	0.21907E-01	0.17928E-02	8.18	1.99094E-02	2.39050E-02	3.99568E-03	18.24
310	2005.0	0.23700E-01	0.21907E-01	0.17928E-02	8.18	1.99094E-02	2.39050E-02	3.99568E-03	18.24
311	2005.0	0.23500E-01	0.21907E-01	0.15928E-02	7.27	1.99051E-02	2.39093E-02	4.00423E-03	18.28
312	2199.0	0.24800E-01	0.23147E-01	0.16525E-02	7.14	2.04774E-02	2.58176E-02	5.34014E-03	23.07
313	2203.0	0.23300E-01	0.23177E-01	0.12331E-03	0.53	2.04373E-02	2.59161E-02	5.47882E-03	23.64
314	2203.0	0.23300E-01	0.23177E-01	0.12331E-03	0.53	2.04373E-02	2.59161E-02	5.47882E-03	23.64
315	2203.0	0.23300E-01	0.23177E-01	0.12331E-03	0.53	2.04373E-02	2.59161E-02	5.47882E-03	23.64
316	2203.0	0.23300E-01	0.23177E-01	0.12331E-03	0.53	2.04373E-02	2.59161E-02	5.47882E-03	23.64
317	813.00	0.26500E-01	0.24912E-01	0.15881E-02	6.37	2.18287E-02	2.79952E-02	6.16645E-03	24.75
318	820.00	0.25100E-01	0.24779E-01	0.32128E-03	1.30	2.17422E-02	2.78152E-02	6.07298E-03	24.51
319	819.00	0.25600E-01	0.24798E-01	0.80247E-03	3.24	2.17636E-02	2.78314E-02	6.06777E-03	24.47
320	820.00	0.25100E-01	0.24779E-01	0.32128E-03	1.30	2.17422E-02	2.78152E-02	6.07298E-03	24.51
321	817.00	0.26100E-01	0.24835E-01	0.12646E-02	5.09	2.17909E-02	2.78798E-02	6.08893E-03	24.52
322	1085.0	0.22400E-01	0.21633E-01	0.76669E-03	3.54	1.99422E-02	2.33244E-02	3.38214E-03	15.63
323	1085.0	0.22900E-01	0.21633E-01	0.12667E-02	5.86	1.99517E-02	2.33150E-02	3.36331E-03	15.55
324	1084.0	0.23100E-01	0.21640E-01	0.14598E-02	6.75	1.99603E-02	2.33202E-02	3.35990E-03	15.53
325	1084.0	0.23300E-01	0.21640E-01	0.16598E-02	7.67	1.99643E-02	2.33161E-02	3.35178E-03	15.49

SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE			PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			% WIDTH
		OBSERVED	PREDICTED	RESIDUAL		LOWER	UPPER	WIDTH	
276	2242.0	0.23100E-01	0.23469E-01	-0.36901E-03	-1.57	2.00156E-02	2.69224E-02	6.90680E-03	29.43
277	803.00	0.27700E-01	0.24619E-01	0.30807E-02	12.51	2.16698E-02	2.75687E-02	5.89881E-03	23.96
278	804.00	0.24400E-01	0.24600E-01	-0.20042E-03	-0.81	2.15687E-02	2.76321E-02	6.06335E-03	24.65
279	804.00	0.25700E-01	0.24600E-01	0.10996E-02	4.47	2.16078E-02	2.75930E-02	5.98520E-03	24.33
280	803.00	0.26600E-01	0.24619E-01	0.19807E-02	8.05	2.16400E-02	2.75985E-02	5.95842E-03	24.20
281	803.00	0.25500E-01	0.24619E-01	0.88075E-03	3.58	2.16083E-02	2.76302E-02	6.02199E-03	24.46
282	1049.0	0.21400E-01	0.21609E-01	-0.20904E-03	-0.97	1.99506E-02	2.32675E-02	3.31693E-03	15.35
283	1048.0	0.21700E-01	0.21616E-01	0.83541E-04	0.39	1.99617E-02	2.32712E-02	3.30945E-03	15.31
284	1046.0	0.21700E-01	0.21631E-01	0.68624E-04	0.32	1.99728E-02	2.32900E-02	3.31721E-03	15.34
285	1047.0	0.21400E-01	0.21624E-01	-0.22390E-03	-1.04	1.99616E-02	2.32862E-02	3.32457E-03	15.37
286	1047.0	0.21900E-01	0.21624E-01	0.27610E-03	1.28	1.99710E-02	2.32768E-02	3.30588E-03	15.29
287	1241.0	0.19500E-01	0.20635E-01	-0.11351E-02	-5.50	1.87010E-02	2.25692E-02	3.86823E-03	18.75
288	1242.0	0.19300E-01	0.20632E-01	-0.13320E-02	-6.46	1.86911E-02	2.25729E-02	3.88187E-03	18.81
289	1241.0	0.19600E-01	0.20635E-01	-0.10351E-02	-5.02	1.87037E-02	2.25665E-02	3.86282E-03	18.72
290	1242.0	0.19500E-01	0.20632E-01	-0.11320E-02	-5.49	1.86965E-02	2.25675E-02	3.87092E-03	18.76
291	1242.0	0.19300E-01	0.20632E-01	-0.13320E-02	-6.46	1.86911E-02	2.25729E-02	3.88187E-03	18.81
292	1431.0	0.20200E-01	0.20326E-01	-0.12572E-03	-0.62	1.81549E-02	2.24965E-02	4.34161E-03	21.36
293	1432.0	0.19900E-01	0.20325E-01	-0.42542E-03	-2.09	1.81452E-02	2.25056E-02	4.36045E-03	21.45
294	1434.0	0.19800E-01	0.20325E-01	-0.52486E-03	-2.58	1.81416E-02	2.25081E-02	4.36650E-03	21.48
295	1433.0	0.19900E-01	0.20325E-01	-0.42514E-03	-2.09	1.81445E-02	2.25057E-02	4.36119E-03	21.46
296	1433.0	0.19900E-01	0.20325E-01	-0.42514E-03	-2.09	1.81445E-02	2.25057E-02	4.36119E-03	21.46
297	1599.0	0.19700E-01	0.20441E-01	-0.74096E-03	-3.62	1.88898E-02	2.19922E-02	3.10242E-03	15.18
298	1596.0	0.19600E-01	0.20436E-01	-0.83615E-03	-4.09	1.88811E-02	2.19912E-02	3.11008E-03	15.22
299	1590.0	0.22300E-01	0.20427E-01	0.18732E-02	9.17	1.89177E-02	2.19359E-02	3.01828E-03	14.78
300	1586.0	0.23900E-01	0.20421E-01	0.34792E-02	17.04	1.89355E-02	2.19061E-02	2.97053E-03	14.55

SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE		RESIDUAL	PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			% WIDTH
		OBSERVED	PREDICTED			LOWER	UPPER	WIDTH	
251	1288.0	0.19800E-01	0.20508E-01	-0.70790E-03	-3.45	1.85329E-02	2.24829E-02	3.95007E-03	19.26
252	1484.0	0.20200E-01	0.20327E-01	-0.12684E-03	-0.62	1.80828E-02	2.25708E-02	4.48801E-03	22.08
253	1483.0	0.20400E-01	0.20327E-01	0.73495E-04	0.36	1.80889E-02	2.25641E-02	4.47517E-03	22.02
254	1485.0	0.20100E-01	0.20327E-01	-0.22719E-03	-1.12	1.80806E-02	2.25738E-02	4.49314E-03	22.10
255	1484.0	0.20100E-01	0.20327E-01	-0.22684E-03	-1.12	1.80802E-02	2.25734E-02	4.49322E-03	22.10
256	1485.0	0.20200E-01	0.20327E-01	-0.12719E-03	-0.63	1.80832E-02	2.25712E-02	4.48794E-03	22.08
257	1659.0	0.19700E-01	0.20557E-01	-0.85691E-03	-4.17	1.87963E-02	2.23175E-02	3.52115E-03	17.13
258	1653.0	0.19600E-01	0.20544E-01	-0.94365E-03	-4.59	1.87751E-02	2.23122E-02	3.53718E-03	17.22
259	1641.0	0.20000E-01	0.20518E-01	-0.51823E-03	-2.53	1.87478E-02	2.22887E-02	3.54085E-03	17.26
260	1638.0	0.21100E-01	0.20512E-01	0.58789E-03	2.87	1.87623E-02	2.22619E-02	3.49958E-03	17.06
261	1653.0	0.20400E-01	0.20544E-01	-0.14365E-03	-0.70	1.87924E-02	2.22949E-02	3.50252E-03	17.05
262	1832.0	0.19700E-01	0.21091E-01	-0.13913E-02	-6.60	1.90469E-02	2.31357E-02	4.08875E-03	19.39
263	1833.0	0.19800E-01	0.21095E-01	-0.12952E-02	-6.14	1.90546E-02	2.31358E-02	4.08117E-03	19.35
264	1832.0	0.20300E-01	0.21091E-01	-0.79128E-03	-3.75	1.90615E-02	2.31210E-02	4.05948E-03	19.25
265	1832.0	0.19900E-01	0.21091E-01	-0.11913E-02	-5.65	1.90528E-02	2.31297E-02	4.07692E-03	19.33
266	1832.0	0.19800E-01	0.21091E-01	-0.12913E-02	-6.12	1.90499E-02	2.31327E-02	4.08281E-03	19.36
267	2044.0	0.22800E-01	0.22129E-01	0.67101E-03	3.03	1.99567E-02	2.43013E-02	4.34458E-03	19.63
268	2048.0	0.22600E-01	0.22153E-01	0.44748E-03	2.02	1.99602E-02	2.43448E-02	4.38453E-03	19.79
269	2047.0	0.22500E-01	0.22147E-01	0.35338E-03	1.60	1.99568E-02	2.43365E-02	4.37966E-03	19.78
270	2047.0	0.22500E-01	0.22147E-01	0.35338E-03	1.60	1.99568E-02	2.43365E-02	4.37966E-03	19.78
271	2049.0	0.22800E-01	0.22158E-01	0.64158E-03	2.90	1.99676E-02	2.43493E-02	4.38166E-03	19.77
272	2238.0	0.23400E-01	0.23438E-01	-0.38387E-04	-0.16	2.00302E-02	2.68466E-02	6.81635E-03	29.08
273	2239.0	0.23600E-01	0.23446E-01	0.15397E-03	0.66	2.00377E-02	2.68544E-02	6.81672E-03	29.07
274	2242.0	0.23100E-01	0.23469E-01	-0.36901E-03	-1.57	2.00156E-02	2.69224E-02	6.90680E-03	29.43
275	2239.0	0.23600E-01	0.23446E-01	0.15397E-03	0.66	2.00377E-02	2.68544E-02	6.81672E-03	29.07

SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE			PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			% WIDTH
		OBSERVED	PREDICTED	RESIDUAL		LOWER	UPPER	WIDTH	
226	1940.0	0.23100E-01	0.21483E-01	0.16166E-02	7.52	1.97059E-02	2.32610E-02	3.55510E-03	16.55
227	1937.0	0.23800E-01	0.21468E-01	0.23316E-02	10.86	1.97119E-02	2.32249E-02	3.51295E-03	16.36
228	1937.0	0.23800E-01	0.21468E-01	0.23316E-02	10.86	1.97119E-02	2.32249E-02	3.51295E-03	16.36
229	1939.0	0.23400E-01	0.21478E-01	0.19216E-02	8.95	1.97094E-02	2.32474E-02	3.53806E-03	16.47
230	1940.0	0.23800E-01	0.21483E-01	0.23166E-02	10.78	1.97193E-02	2.32475E-02	3.52822E-03	16.42
231	2127.0	0.24500E-01	0.22580E-01	0.19197E-02	8.50	2.02888E-02	2.48719E-02	4.58312E-03	20.30
232	2141.0	0.20300E-01	0.22675E-01	-0.23751E-02	-10.47	2.01873E-02	2.51628E-02	4.97541E-03	21.94
233	2139.0	0.22200E-01	0.22661E-01	-0.46141E-03	-2.04	2.02410E-02	2.50819E-02	4.84091E-03	21.36
234	2146.0	0.21600E-01	0.22709E-01	-0.11093E-02	-4.88	2.02287E-02	2.51899E-02	4.96122E-03	21.85
235	2143.0	0.22000E-01	0.22689E-01	-0.68873E-03	-3.04	2.02379E-02	2.51395E-02	4.90157E-03	21.60
236	2145.0	0.21300E-01	0.22702E-01	-0.14024E-02	-6.18	2.02197E-02	2.51852E-02	4.96552E-03	21.87
237	838.00	0.23800E-01	0.24002E-01	-0.20199E-03	-0.84	2.13045E-02	2.66995E-02	5.39502E-03	22.48
238	842.00	0.22500E-01	0.23937E-01	-0.14366E-02	-6.00	2.12458E-02	2.66274E-02	5.38162E-03	22.48
239	839.00	0.22700E-01	0.23936E-01	-0.12856E-02	-5.36	2.12670E-02	2.67041E-02	5.43705E-03	22.67
240	839.00	0.22600E-01	0.23986E-01	-0.13856E-02	-5.78	2.12639E-02	2.67072E-02	5.44333E-03	22.69
241	841.00	0.22300E-01	0.23953E-01	-0.16529E-02	-6.90	2.12446E-02	2.66611E-02	5.41653E-03	22.61
242	1096.0	0.20700E-01	0.21292E-01	-0.59166E-03	-2.78	1.96812E-02	2.29021E-02	3.22087E-03	15.13
243	1096.0	0.20600E-01	0.21292E-01	-0.69166E-03	-3.25	1.96794E-02	2.29040E-02	3.22459E-03	15.14
244	1094.0	0.20600E-01	0.21304E-01	-0.70398E-03	-3.30	1.96908E-02	2.29171E-02	3.22629E-03	15.14
245	1095.0	0.20500E-01	0.21298E-01	-0.79781E-03	-3.75	1.96832E-02	2.29124E-02	3.22915E-03	15.16
246	1095.0	0.20500E-01	0.21298E-01	-0.79781E-03	-3.75	1.96832E-02	2.29124E-02	3.22915E-03	15.16
247	1285.0	0.19900E-01	0.20515E-01	-0.61493E-03	-3.00	1.85463E-02	2.24836E-02	3.93727E-03	19.19
248	1288.0	0.19400E-01	0.20508E-01	-0.11079E-02	-5.40	1.85230E-02	2.24928E-02	3.96982E-03	19.36
249	1287.0	0.20000E-01	0.20510E-01	-0.51023E-03	-2.49	1.85417E-02	2.24787E-02	3.93702E-03	19.20
250	1286.0	0.19900E-01	0.20513E-01	-0.61257E-03	-2.99	1.85427E-02	2.24825E-02	3.93978E-03	19.21

SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE		RESIDUAL	PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			% WIDTH
		OBSERVED	PREDICTED			LOWER	UPPER	WIDTH	
201	1065.0	0.19100E-01	0.21141E-01	-0.20406E-02	-9.65	1.86018E-02	2.36794E-02	5.07757E-03	24.02
202	1065.0	0.19500E-01	0.21141E-01	-0.16406E-02	-7.76	1.86148E-02	2.36664E-02	5.05162E-03	23.90
203	1063.0	0.19500E-01	0.21153E-01	-0.16531E-02	-7.81	1.86174E-02	2.36887E-02	5.07126E-03	23.97
204	1065.0	0.19600E-01	0.21141E-01	-0.15406E-02	-7.29	1.86187E-02	2.36625E-02	5.04377E-03	23.86
205	1065.0	0.19700E-01	0.21141E-01	-0.14406E-02	-6.81	1.86216E-02	2.36596E-02	5.03793E-03	23.83
206	1187.0	0.18600E-01	0.20553E-01	-0.19526E-02	-9.50	1.84102E-02	2.26951E-02	4.28482E-03	20.85
207	1188.0	0.19000E-01	0.20549E-01	-0.15491E-02	-7.54	1.84205E-02	2.26776E-02	4.25705E-03	20.72
208	1185.0	0.19300E-01	0.20560E-01	-0.12598E-02	-6.13	1.84330E-02	2.26867E-02	4.25366E-03	20.69
209	1183.0	0.19000E-01	0.20567E-01	-0.15671E-02	-7.62	1.84268E-02	2.27074E-02	4.28057E-03	20.81
210	1187.0	0.19200E-01	0.20553E-01	-0.13526E-02	-6.58	1.84270E-02	2.26783E-02	4.25123E-03	20.68
211	1402.0	0.20100E-01	0.20152E-01	-0.51837E-04	-0.26	1.82590E-02	2.20447E-02	3.78575E-03	18.79
212	1397.0	0.20200E-01	0.20154E-01	0.46194E-04	0.23	1.82594E-02	2.20483E-02	3.78889E-03	18.80
213	1399.0	0.19800E-01	0.20153E-01	-0.35298E-03	-1.75	1.82508E-02	2.20552E-02	3.80442E-03	18.88
214	1397.0	0.20200E-01	0.20154E-01	0.46194E-04	0.23	1.82594E-02	2.20483E-02	3.78889E-03	18.80
215	1399.0	0.20600E-01	0.20153E-01	0.44702E-03	2.22	1.82694E-02	2.20366E-02	3.76723E-03	18.69
216	1529.0	0.21500E-01	0.20201E-01	0.12992E-02	6.43	1.83655E-02	2.20362E-02	3.67071E-03	18.17
217	1531.0	0.20800E-01	0.20203E-01	0.59697E-03	2.95	1.83546E-02	2.20515E-02	3.69696E-03	18.30
218	1532.0	0.20900E-01	0.20204E-01	0.69584E-03	3.44	1.83585E-02	2.20498E-02	3.69124E-03	18.27
219	1532.0	0.20900E-01	0.20204E-01	0.69584E-03	3.44	1.83585E-02	2.20498E-02	3.69124E-03	18.27
220	1531.0	0.21100E-01	0.20203E-01	0.89697E-03	4.44	1.83612E-02	2.20449E-02	3.68368E-03	18.23
221	1743.0	0.19100E-01	0.20669E-01	-0.15689E-02	-7.59	1.90263E-02	2.23116E-02	3.28522E-03	15.89
222	1739.0	0.19700E-01	0.20656E-01	-0.95611E-03	-4.63	1.90242E-02	2.22880E-02	3.26381E-03	15.80
223	1738.0	0.19200E-01	0.20653E-01	-0.14529E-02	-7.03	1.90099E-02	2.22959E-02	3.28600E-03	15.91
224	1738.0	0.19100E-01	0.20653E-01	-0.15529E-02	-7.52	1.90074E-02	2.22984E-02	3.29095E-03	15.93
225	1742.0	0.19300E-01	0.20666E-01	-0.13657E-02	-6.61	1.90267E-02	2.23048E-02	3.27812E-03	15.86

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SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE			PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			% WIDTH
		OBSERVED	PREDICTED	RESIDUAL		LOWER	UPPER	WIDTH	
176	1581.0	0.21300E-01	0.20272E-01	0.10277E-02	5.07	1.84260E-02	2.21185E-02	3.69247E-03	18.21
177	1584.0	0.21200E-01	0.20277E-01	0.92277E-03	4.55	1.84320E-02	2.21225E-02	3.69053E-03	18.20
178	1582.0	0.21000E-01	0.20274E-01	0.72610E-03	3.58	1.84223E-02	2.21255E-02	3.70322E-03	18.27
179	1582.0	0.21200E-01	0.20274E-01	0.92610E-03	4.57	1.84266E-02	2.21212E-02	3.69465E-03	18.22
180	1795.0	0.20900E-01	0.20349E-01	0.50574E-04	0.24	1.91354E-02	2.25634E-02	3.42796E-03	16.44
181	1797.0	0.20900E-01	0.20857E-01	0.43133E-04	0.21	1.91429E-02	2.25708E-02	3.42790E-03	16.44
182	1795.0	0.21000E-01	0.20849E-01	0.15057E-03	0.72	1.91376E-02	2.25613E-02	3.42372E-03	16.42
183	1795.0	0.21100E-01	0.20849E-01	0.25057E-03	1.20	1.91397E-02	2.25592E-02	3.41951E-03	16.40
184	1797.0	0.20900E-01	0.20857E-01	0.43133E-04	0.21	1.91429E-02	2.25708E-02	3.42790E-03	16.44
185	1984.0	0.23200E-01	0.21713E-01	0.14867E-02	6.85	1.97237E-02	2.37030E-02	3.97922E-03	18.33
186	1986.0	0.23900E-01	0.21724E-01	0.21758E-02	10.02	1.97425E-02	2.37059E-02	3.96335E-03	18.24
187	1984.0	0.24300E-01	0.21713E-01	0.25867E-02	11.91	1.97466E-02	2.36801E-02	3.93351E-03	18.12
188	1986.0	0.23500E-01	0.21724E-01	0.17758E-02	8.17	1.97338E-02	2.37146E-02	3.98085E-03	18.32
189	1986.0	0.23700E-01	0.21724E-01	0.19758E-02	9.09	1.97382E-02	2.37102E-02	3.97205E-03	18.28
190	2195.0	0.24700E-01	0.23057E-01	0.16430E-02	7.13	1.99811E-02	2.61330E-02	6.15187E-03	26.68
191	2198.0	0.22000E-01	0.23079E-01	-0.10790E-02	-4.68	1.98888E-02	2.62693E-02	6.38046E-03	27.65
192	2196.0	0.20900E-01	0.23064E-01	-0.21644E-02	-9.38	1.98496E-02	2.62792E-02	6.42959E-03	27.88
193	2199.0	0.21200E-01	0.23086E-01	-0.18864E-02	-8.17	1.98590E-02	2.63138E-02	6.45479E-03	27.96
194	2198.0	0.21100E-01	0.23079E-01	-0.19790E-02	-8.58	1.98564E-02	2.63017E-02	6.44524E-03	27.93
195	2198.0	0.21100E-01	0.23079E-01	-0.19790E-02	-8.58	1.98564E-02	2.63017E-02	6.44524E-03	27.93
196	826.00	0.22800E-01	0.23584E-01	-0.78366E-03	-3.32	1.95601E-02	2.76072E-02	8.04703E-03	34.12
197	827.00	0.22600E-01	0.23568E-01	-0.96808E-03	-4.11	1.95480E-02	2.75882E-02	8.04025E-03	34.11
198	829.00	0.21700E-01	0.23537E-01	-0.18371E-02	-7.81	1.95001E-02	2.75742E-02	8.07411E-03	34.30
199	827.00	0.21900E-01	0.23568E-01	-0.16681E-02	-7.08	1.95158E-02	2.76203E-02	8.10449E-03	34.39
200	827.00	0.21900E-01	0.23568E-01	-0.16681E-02	-7.08	1.95158E-02	2.76203E-02	8.10449E-03	34.39

SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE			PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			% WIDTH
		OBSERVED	PREDICTED	RESIDUAL		LOWER	UPPER	WIDTH	
151	1019.0	0.29400E-01	0.26273E-01	0.31275E-02	11.90	2.15117E-02	3.10334E-02	9.52165E-03	36.24
152	1020.0	0.30000E-01	0.26256E-01	0.37444E-02	14.26	2.15310E-02	3.09803E-02	9.44926E-03	35.99
153	1019.0	0.28400E-01	0.26273E-01	0.21275E-02	8.10	2.14704E-02	3.10746E-02	9.60421E-03	36.56
154	1019.0	0.29400E-01	0.26273E-01	0.31275E-02	11.90	2.15117E-02	3.10334E-02	9.52165E-03	36.24
155	880.00	0.19900E-01	0.22823E-01	-0.29229E-02	-12.81	1.92121E-02	2.64337E-02	7.22160E-03	31.64
156	885.00	0.19300E-01	0.22760E-01	-0.34601E-02	-15.20	1.91736E-02	2.63465E-02	7.17288E-03	31.52
157	884.00	0.19600E-01	0.22773E-01	-0.31725E-02	-13.93	1.91894E-02	2.63556E-02	7.16620E-03	31.47
158	884.00	0.19900E-01	0.22773E-01	-0.28725E-02	-12.61	1.92028E-02	2.63423E-02	7.13957E-03	31.35
159	880.00	0.19600E-01	0.22823E-01	-0.32229E-02	-14.12	1.91986E-02	2.64471E-02	7.24854E-03	31.76
160	1119.0	0.20000E-01	0.20841E-01	-0.84073E-03	-4.03	1.85671E-02	2.31143E-02	4.54717E-03	21.82
161	1122.0	0.19500E-01	0.20826E-01	-0.13260E-02	-6.37	1.85483E-02	2.31037E-02	4.55537E-03	21.87
162	1117.0	0.19700E-01	0.20851E-01	-0.11506E-02	-5.52	1.85614E-02	2.31399E-02	4.57855E-03	21.96
163	1118.0	0.19800E-01	0.20846E-01	-0.10457E-02	-5.02	1.85626E-02	2.31288E-02	4.56622E-03	21.90
164	1119.0	0.20100E-01	0.20841E-01	-0.74073E-03	-3.55	1.85697E-02	2.31118E-02	4.54209E-03	21.79
165	1240.0	0.20500E-01	0.20388E-01	0.11209E-03	0.55	1.84275E-02	2.23484E-02	3.92089E-03	19.23
166	1242.0	0.19300E-01	0.20383E-01	-0.10826E-02	-5.31	1.83960E-02	2.23692E-02	3.97317E-03	19.49
167	1241.0	0.19300E-01	0.20385E-01	-0.10853E-02	-5.32	1.83971E-02	2.23734E-02	3.97633E-03	19.51
168	1241.0	0.19700E-01	0.20385E-01	-0.68526E-03	-3.36	1.84069E-02	2.23637E-02	3.95682E-03	19.41
169	1240.0	0.19600E-01	0.20388E-01	-0.78791E-03	-3.86	1.84057E-02	2.23701E-02	3.96445E-03	19.45
170	1446.0	0.21700E-01	0.20148E-01	0.15523E-02	7.70	1.82493E-02	2.20461E-02	3.79677E-03	18.84
171	1448.0	0.21700E-01	0.20148E-01	0.15520E-02	7.70	1.82513E-02	2.20447E-02	3.79341E-03	18.83
172	1451.0	0.21700E-01	0.20149E-01	0.15513E-02	7.70	1.82545E-02	2.20428E-02	3.78837E-03	18.80
173	1449.0	0.21900E-01	0.20148E-01	0.17518E-02	8.69	1.82570E-02	2.20395E-02	3.78250E-03	18.77
174	1449.0	0.21500E-01	0.20148E-01	0.13518E-02	6.71	1.82486E-02	2.20478E-02	3.79921E-03	18.86
175	1582.0	0.21100E-01	0.20274E-01	0.82610E-03	4.07	1.84244E-02	2.21234E-02	3.69892E-03	18.24

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SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE		RESIDUAL	PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			
		OBSERVED	PREDICTED			LOWER	UPPER	WIDTH	% WIDTH
126	1158.0	0.21800E-01	0.22157E-01	-0.35671E-03	-1.61	2.05275E-02	2.37860E-02	3.25848E-03	14.71
127	1158.0	0.21600E-01	0.22157E-01	-0.55671E-03	-2.51	2.05236E-02	2.37898E-02	3.26615E-03	14.74
128	1157.0	0.21600E-01	0.22163E-01	-0.56343E-03	-2.54	2.05270E-02	2.37999E-02	3.27292E-03	14.77
129	1158.0	0.21800E-01	0.22157E-01	-0.35671E-03	-1.61	2.05275E-02	2.37860E-02	3.25848E-03	14.71
130	1030.0	0.24100E-01	0.23260E-01	0.83976E-03	3.61	2.11534E-02	2.53671E-02	4.21372E-03	18.12
131	1029.0	0.24800E-01	0.23271E-01	0.15289E-02	6.57	2.11724E-02	2.53697E-02	4.19730E-03	18.04
132	1030.0	0.24800E-01	0.23260E-01	0.15398E-02	6.62	2.11683E-02	2.53521E-02	4.18378E-03	17.99
133	1029.0	0.24500E-01	0.23271E-01	0.12289E-02	5.28	2.11662E-02	2.53759E-02	4.20963E-03	18.09
134	1029.0	0.24800E-01	0.23271E-01	0.15289E-02	6.57	2.11724E-02	2.53697E-02	4.19730E-03	18.04
135	876.00	0.24200E-01	0.25482E-01	-0.12820E-02	-5.03	2.21587E-02	2.88054E-02	6.64671E-03	26.08
136	874.00	0.23400E-01	0.25520E-01	-0.21198E-02	-8.31	2.21436E-02	2.88960E-02	6.75233E-03	26.46
137	876.00	0.25100E-01	0.25482E-01	-0.38201E-03	-1.50	2.21888E-02	2.87752E-02	6.58635E-03	25.85
138	876.00	0.24600E-01	0.25482E-01	-0.88201E-03	-3.46	2.21723E-02	2.87917E-02	6.61933E-03	25.98
139	876.00	0.25100E-01	0.25482E-01	-0.38201E-03	-1.50	2.21888E-02	2.87752E-02	6.58635E-03	25.85
140	1290.0	0.22900E-01	0.23281E-01	-0.38145E-03	-1.64	1.99847E-02	2.65782E-02	6.59343E-03	28.32
141	1291.0	0.22900E-01	0.23275E-01	-0.37493E-03	-1.61	1.99832E-02	2.65666E-02	6.58340E-03	28.29
142	1290.0	0.22900E-01	0.23281E-01	-0.38145E-03	-1.64	1.99847E-02	2.65782E-02	6.59343E-03	28.32
143	1289.0	0.22400E-01	0.23288E-01	-0.88801E-03	-3.81	1.99680E-02	2.66080E-02	6.63994E-03	28.51
144	1291.0	0.22600E-01	0.23275E-01	-0.67493E-03	-2.90	1.99722E-02	2.65776E-02	6.60541E-03	28.38
145	1148.0	0.24900E-01	0.24503E-01	0.39704E-03	1.62	2.05951E-02	2.84108E-02	7.81565E-03	31.90
146	1147.0	0.26000E-01	0.24514E-01	0.14861E-02	6.06	2.06402E-02	2.83877E-02	7.74751E-03	31.60
147	1147.0	0.26400E-01	0.24514E-01	0.18861E-02	7.69	2.06545E-02	2.83733E-02	7.71878E-03	31.49
148	1147.0	0.25600E-01	0.24514E-01	0.10861E-02	4.43	2.06249E-02	2.84030E-02	7.77807E-03	31.73
149	1146.0	0.26000E-01	0.24525E-01	0.14751E-02	6.01	2.06432E-02	2.84066E-02	7.76346E-03	31.66
150	1018.0	0.28400E-01	0.26289E-01	0.21105E-02	8.03	2.14752E-02	3.11037E-02	9.62851E-03	36.62

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SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE		RESIDUAL	PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			% WIDTH
		OBSERVED	PREDICTED			LOWER	UPPER	WIDTH	
101	1318.0	0.23900E-01	0.23108E-01	0.79182E-03	3.43	2.01234E-02	2.60929E-02	5.96951E-03	25.83
102	1320.0	0.23000E-01	0.23097E-01	-0.96541E-04	-0.42	2.00917E-02	2.61014E-02	6.00968E-03	26.02
103	1319.0	0.23000E-01	0.23102E-01	-0.10235E-03	-0.44	2.00932E-02	2.61115E-02	6.01826E-03	26.05
104	1318.0	0.23000E-01	0.23108E-01	-0.10818E-03	-0.47	2.00947E-02	2.61216E-02	6.02688E-03	26.08
105	1319.0	0.23100E-01	0.23102E-01	-0.23493E-05	-0.01	2.00967E-02	2.61080E-02	6.01124E-03	26.02
106	1175.0	0.22300E-01	0.24221E-01	-0.19209E-02	-7.93	2.04203E-02	2.80214E-02	7.60109E-03	31.38
107	1174.0	0.22500E-01	0.24231E-01	-0.17308E-02	-7.14	2.04315E-02	2.80302E-02	7.59877E-03	31.36
108	1173.0	0.22700E-01	0.24241E-01	-0.15409E-02	-6.36	2.04425E-02	2.80392E-02	7.59663E-03	31.34
109	1173.0	0.22600E-01	0.24241E-01	-0.16409E-02	-6.77	2.04383E-02	2.80434E-02	7.60510E-03	31.37
110	1173.0	0.23100E-01	0.24241E-01	-0.11409E-02	-4.71	2.04593E-02	2.80225E-02	7.56321E-03	31.20
111	1044.0	0.24200E-01	0.25867E-01	-0.16671E-02	-6.44	2.11339E-02	3.06002E-02	9.46630E-03	36.60
112	1044.0	0.24200E-01	0.25867E-01	-0.16671E-02	-6.44	2.11339E-02	3.06002E-02	9.46630E-03	36.60
113	1045.0	0.24100E-01	0.25852E-01	-0.17515E-02	-6.78	2.11251E-02	3.05779E-02	9.45278E-03	36.57
114	1045.0	0.24000E-01	0.25852E-01	-0.18515E-02	-7.16	2.11204E-02	3.05827E-02	9.46234E-03	36.60
115	1046.0	0.23900E-01	0.25836E-01	-0.19361E-02	-7.49	2.11116E-02	3.05605E-02	9.44894E-03	36.57
116	1440.0	0.21000E-01	0.21112E-01	-0.11202E-03	-0.53	1.96523E-02	2.25717E-02	2.91943E-03	13.83
117	1440.0	0.21000E-01	0.21112E-01	-0.11202E-03	-0.53	1.96523E-02	2.25717E-02	2.91943E-03	13.83
118	1439.0	0.20800E-01	0.21113E-01	-0.31327E-03	-1.48	1.96500E-02	2.25765E-02	2.92648E-03	13.86
119	1439.0	0.21000E-01	0.21113E-01	-0.11327E-03	-0.54	1.96533E-02	2.25733E-02	2.92003E-03	13.83
120	1439.0	0.20800E-01	0.21113E-01	-0.31327E-03	-1.48	1.96500E-02	2.25765E-02	2.92648E-03	13.86
121	1301.0	0.20300E-01	0.21437E-01	-0.11375E-02	-5.31	1.99824E-02	2.28925E-02	2.91017E-03	13.58
122	1303.0	0.20100E-01	0.21430E-01	-0.13304E-02	-6.21	1.99733E-02	2.28875E-02	2.91418E-03	13.60
123	1301.0	0.20500E-01	0.21437E-01	-0.93745E-03	-4.37	1.99857E-02	2.28892E-02	2.90345E-03	13.54
124	1300.0	0.20300E-01	0.21441E-01	-0.11410E-02	-5.32	1.99850E-02	2.28970E-02	2.91197E-03	13.58
125	1158.0	0.21600E-01	0.22157E-01	-0.55671E-03	-2.51	2.05236E-02	2.37898E-02	3.26615E-03	14.74

SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE		RESIDUAL	PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			
		OBSERVED	PREDICTED			LOWER	UPPER	WIDTH	% WIDTH
76	1446.0	0.22900E-C1	0.21105E-01	0.17952E-02	8.51	1.96731E-02	2.25365E-02	2.86336E-03	13.57
77	1445.0	0.22700E-C1	0.21106E-01	0.15940E-02	7.55	1.96711E-02	2.25409E-02	2.86983E-03	13.60
78	1445.0	0.22700E-C1	0.21106E-01	0.15940E-02	7.55	1.96711E-02	2.25409E-02	2.86983E-03	13.60
79	1445.0	0.22400E-C1	0.21106E-01	0.12940E-02	6.13	1.96664E-02	2.25456E-02	2.87920E-03	13.64
80	1445.0	0.22700E-C1	0.21106E-01	0.15940E-02	7.55	1.96711E-02	2.25409E-02	2.86983E-03	13.60
81	1309.0	0.22000E-C1	0.21410E-01	0.59023E-03	2.76	1.99732E-02	2.28463E-02	2.87307E-03	13.42
82	1309.0	0.21900E-C1	0.21410E-01	0.49023E-03	2.29	1.99714E-02	2.28481E-02	2.87667E-03	13.44
83	1307.0	0.22200E-01	0.21417E-01	0.78342E-03	3.66	1.99816E-02	2.28515E-02	2.86991E-03	13.40
84	1308.0	0.22200E-01	0.21413E-01	0.78684E-03	3.67	1.99790E-02	2.28473E-02	2.86827E-03	13.39
85	1308.0	0.21800E-01	0.21413E-01	0.38684E-03	1.81	1.99726E-02	2.28538E-02	2.88119E-03	13.46
86	1160.0	0.23600E-01	0.22143E-01	0.14566E-02	6.58	2.05507E-02	2.37360E-02	3.18529E-03	14.38
87	1159.0	0.24200E-01	0.22150E-01	0.20500E-02	9.25	2.05641E-02	2.37360E-02	3.17189E-03	14.32
88	1158.0	0.24000E-01	0.22157E-01	0.18433E-02	8.32	2.05644E-02	2.37490E-02	3.18464E-03	14.37
89	1158.0	0.23900E-01	0.22157E-01	0.17433E-02	7.87	2.05627E-02	2.37507E-02	3.18805E-03	14.39
90	1157.0	0.24200E-01	0.22163E-01	0.20366E-02	9.19	2.05709E-02	2.37559E-02	3.18502E-03	14.37
91	1027.0	0.25900E-01	0.23293E-01	0.26072E-02	11.19	2.11992E-02	2.53865E-02	4.18727E-03	17.98
92	1026.0	0.25900E-01	0.23304E-01	0.25962E-02	11.14	2.12033E-02	2.54042E-02	4.20088E-03	18.03
93	1027.0	0.26100E-01	0.23293E-01	0.28072E-02	12.05	2.12032E-02	2.53825E-02	4.17927E-03	17.94
94	1027.0	0.25900E-01	0.23293E-01	0.26072E-02	11.19	2.11992E-02	2.53865E-02	4.18727E-03	17.98
95	1025.0	0.25900E-01	0.23315E-01	0.25853E-02	11.09	2.12075E-02	2.54220E-02	4.21454E-03	18.08
96	875.00	0.26000E-01	0.25501E-01	0.49912E-03	1.96	2.22152E-02	2.87865E-02	6.57126E-03	25.77
97	873.00	0.26700E-01	0.25539E-01	0.11612E-02	4.55	2.22507E-02	2.88269E-02	6.57619E-03	25.75
98	872.00	0.26600E-01	0.25558E-01	0.10421E-02	4.08	2.22544E-02	2.88614E-02	6.60705E-03	25.85
99	872.00	0.26700E-01	0.25558E-01	0.11421E-02	4.47	2.22576E-02	2.88582E-02	6.60059E-03	25.83
100	872.00	0.26700E-01	0.25558E-01	0.11421E-02	4.47	2.22576E-02	2.88582E-02	6.60059E-03	25.83

SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE		RESIDUAL	PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			
		OBSERVED	PREDICTED			LOWER	UPPER	WIDTH	% WIDTH
51	1155.0	0.22900E-01	0.20377E-01	0.25233E-02	12.38	1.82716E-02	2.24818E-02	4.21022E-03	20.66
52	1157.0	0.22600E-01	0.20369E-01	0.22306E-02	10.95	1.82626E-02	2.24761E-02	4.21350E-03	20.69
53	1156.0	0.22300E-01	0.20373E-01	0.19270E-02	9.46	1.82568E-02	2.24892E-02	4.23242E-03	20.77
54	1157.0	0.22300E-01	0.20369E-01	0.19306E-02	9.48	1.82559E-02	2.24829E-02	4.22699E-03	20.75
55	1157.0	0.22300E-01	0.20369E-01	0.19306E-02	9.48	1.82559E-02	2.24829E-02	4.22699E-03	20.75
56	1296.0	0.20700E-01	0.20026E-01	0.67449E-03	3.37	1.80331E-02	2.20180E-02	3.98489E-03	19.90
57	1297.0	0.20700E-01	0.20024E-01	0.67591E-03	3.38	1.80331E-02	2.20151E-02	3.98193E-03	19.89
58	1297.0	0.21100E-01	0.20024E-01	0.10759E-02	5.37	1.80428E-02	2.20053E-02	3.96250E-03	19.79
59	1296.0	0.21100E-01	0.20026E-01	0.10745E-02	5.37	1.80428E-02	2.20082E-02	3.96545E-03	19.80
60	1297.0	0.21100E-01	0.20024E-01	0.10759E-02	5.37	1.80428E-02	2.20053E-02	3.96250E-03	19.79
61	1147.0	0.24600E-01	0.20711E-01	0.38891E-02	18.78	1.88823E-02	2.25394E-02	3.65704E-03	17.66
62	1145.0	0.24600E-01	0.20720E-01	0.38804E-02	18.73	1.88861E-02	2.25531E-02	3.66701E-03	17.70
63	1145.0	0.25300E-01	0.20720E-01	0.45804E-02	22.11	1.88987E-02	2.25405E-02	3.64186E-03	17.58
64	1146.0	0.24900E-01	0.20715E-01	0.41848E-02	20.20	1.88896E-02	2.25409E-02	3.65133E-03	17.63
65	1146.0	0.24900E-01	0.20715E-01	0.41848E-02	20.20	1.88896E-02	2.25409E-02	3.65133E-03	17.63
66	1021.0	0.25300E-01	0.21439E-01	0.38608E-02	18.01	1.93829E-02	2.34955E-02	4.11261E-03	19.18
67	1016.0	0.27400E-01	0.21477E-01	0.59235E-02	27.58	1.94382E-02	2.35148E-02	4.07659E-03	18.98
68	1017.0	0.27400E-01	0.21469E-01	0.59310E-02	27.63	1.94353E-02	2.35027E-02	4.06744E-03	18.95
69	1016.0	0.27000E-01	0.21477E-01	0.55235E-02	25.72	1.94306E-02	2.35225E-02	4.09194E-03	19.05
70	1017.0	0.27400E-01	0.21469E-01	0.59310E-02	27.63	1.94353E-02	2.35027E-02	4.06744E-03	18.95
71	868.00	0.29600E-01	0.22979E-01	0.66214E-02	28.82	2.01845E-02	2.57726E-02	5.58810E-03	24.32
72	866.00	0.28000E-01	0.23005E-01	0.49948E-02	21.71	2.01556E-02	2.58549E-02	5.69927E-03	24.77
73	865.00	0.28500E-01	0.23019E-01	0.54814E-02	23.81	2.01733E-02	2.58640E-02	5.69074E-03	24.72
74	866.00	0.29100E-01	0.23005E-01	0.60948E-02	26.49	2.01830E-02	2.58275E-02	5.64450E-03	24.54
75	864.00	0.28500E-01	0.23032E-01	0.54679E-02	23.74	2.01784E-02	2.58857E-02	5.70731E-03	24.78

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SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE		RESIDUAL	PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			
		OBSERVED	PREDICTED			LOWER	UPPER	WIDTH	% WIDTH
26	1175.0	0.21700E-01	0.20597E-01	0.11031E-02	5.36	1.87562E-02	2.24375E-02	3.68128E-03	17.87
27	1172.0	0.21300E-01	0.20608E-01	0.69163E-03	3.36	1.87527E-02	2.24641E-02	3.71136E-03	18.01
28	1171.0	0.21400E-01	0.20612E-01	0.78776E-03	3.82	1.87564E-02	2.24681E-02	3.71168E-03	18.01
29	1172.0	0.21400E-01	0.20608E-01	0.79163E-03	3.84	1.87547E-02	2.24620E-02	3.70726E-03	17.99
30	1172.0	0.21000E-01	0.20608E-01	0.39163E-03	1.90	1.87461E-02	2.24707E-02	3.72461E-03	18.07
31	1046.0	0.21600E-01	0.21263E-01	0.33688E-03	1.58	1.91465E-02	2.33797E-02	4.23319E-03	19.91
32	1044.0	0.21000E-01	0.21277E-01	-0.27657E-03	-1.30	1.91362E-02	2.34169E-02	4.28075E-03	20.12
33	1044.0	0.21500E-01	0.21277E-01	0.22343E-03	1.05	1.91487E-02	2.34044E-02	4.25566E-03	20.00
34	1042.0	0.21300E-01	0.21290E-01	0.98683E-05	0.05	1.91484E-02	2.34318E-02	4.28340E-03	20.12
35	1042.0	0.21200E-01	0.21290E-01	-0.90132E-04	-0.42	1.91459E-02	2.34343E-02	4.28843E-03	20.14
36	891.00	0.22000E-01	0.22686E-01	-0.68628E-03	-3.03	1.98219E-02	2.55507E-02	5.72876E-03	25.25
37	891.00	0.22400E-01	0.22686E-01	-0.28628E-03	-1.26	1.98347E-02	2.55379E-02	5.70325E-03	25.14
38	890.00	0.22300E-01	0.22698E-01	-0.39847E-03	-1.76	1.98354E-02	2.55615E-02	5.72608E-03	25.23
39	890.00	0.22200E-01	0.22698E-01	-0.49847E-03	-2.20	1.98324E-02	2.55645E-02	5.73212E-03	25.25
40	890.00	0.21500E-01	0.22698E-01	-0.11985E-02	-5.28	1.98094E-02	2.55875E-02	5.77813E-03	25.46
41	895.00	0.21000E-01	0.22138E-01	-0.11383E-02	-5.14	1.90090E-02	2.52676E-02	6.25856E-03	28.27
42	893.00	0.21300E-01	0.22160E-01	-0.86012E-03	-3.88	1.90262E-02	2.52941E-02	6.26787E-03	28.28
43	893.00	0.20700E-01	0.22160E-01	-0.14601E-02	-6.59	1.90039E-02	2.53164E-02	6.31249E-03	28.49
44	892.00	0.21300E-01	0.22171E-01	-0.87109E-03	-3.93	1.90293E-02	2.53129E-02	6.28362E-03	28.34
45	890.00	0.21600E-01	0.22193E-01	-0.59314E-03	-2.67	1.90464E-02	2.53398E-02	6.29340E-03	28.36
46	1076.0	0.23600E-01	0.20728E-01	0.28718E-02	13.85	1.84432E-02	2.30131E-02	4.56991E-03	22.05
47	1076.0	0.23600E-01	0.20728E-01	0.28718E-02	13.85	1.84432E-02	2.30131E-02	4.56991E-03	22.05
48	1077.0	0.23300E-01	0.20723E-01	0.25771E-02	12.44	1.84344E-02	2.30114E-02	4.57693E-03	22.09
49	1077.0	0.23600E-01	0.20723E-01	0.28771E-02	13.88	1.84418E-02	2.30040E-02	4.56213E-03	22.01
50	1077.0	0.23900E-01	0.20723E-01	0.31771E-02	15.33	1.84487E-02	2.29970E-02	4.54832E-03	21.95

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SAMPLE NUMBER	INDE- PENDENT VARIABLE	DEPENDENT VARIABLE		RESIDUAL	PERCENT DEVIATION	90.0% CONFIDENCE LIMITS			
		OBSERVED	PREDICTED			LOWER	UPPER	WIDTH	% WIDTH
1	954.00	0.20200E-01	0.21565E-01	-0.13651E-02	-6.33	1.88199E-02	2.43103E-02	5.49035E-03	25.46
2	953.00	0.19900E-01	0.21574E-01	-0.16738E-02	-7.76	1.88117E-02	2.43359E-02	5.52424E-03	25.61
3	951.00	0.20000E-01	0.21591E-01	-0.15912E-02	-7.37	1.88201E-02	2.43623E-02	5.54226E-03	25.67
4	948.00	0.20000E-01	0.21618E-01	-0.16176E-02	-7.48	1.88272E-02	2.44080E-02	5.58076E-03	25.82
5	946.00	0.19900E-01	0.21635E-01	-0.17354E-02	-8.02	1.88283E-02	2.44425E-02	5.61419E-03	25.95
6	1125.0	0.19300E-01	0.20495E-01	-0.11952E-02	-5.83	1.82656E-02	2.27249E-02	4.45926E-03	21.76
7	1126.0	0.19200E-01	0.20491E-01	-0.12910E-02	-6.30	1.82618E-02	2.27202E-02	4.45843E-03	21.76
8	1126.0	0.19300E-01	0.20491E-01	-0.11910E-02	-5.81	1.82646E-02	2.27174E-02	4.45282E-03	21.73
9	1126.0	0.19500E-01	0.20491E-01	-0.99101E-03	-4.84	1.82702E-02	2.27119E-02	4.44171E-03	21.68
10	1125.0	0.19700E-01	0.20495E-01	-0.79524E-03	-3.88	1.82771E-02	2.27134E-02	4.43624E-03	21.65
11	1202.0	0.19500E-01	0.20224E-01	-0.72400E-03	-3.58	1.81303E-02	2.23177E-02	4.18735E-03	20.70
12	1203.0	0.19600E-01	0.20221E-01	-0.62117E-03	-3.07	1.81327E-02	2.23096E-02	4.17690E-03	20.66
13	1205.0	0.19200E-01	0.20216E-01	-0.10155E-02	-5.02	1.81205E-02	2.23106E-02	4.19015E-03	20.73
14	1203.0	0.19300E-01	0.20221E-01	-0.92117E-03	-4.56	1.81247E-02	2.23176E-02	4.19295E-03	20.74
15	1204.0	0.19400E-01	0.20218E-01	-0.81835E-03	-4.05	1.81266E-02	2.23101E-02	4.18345E-03	20.69
16	1347.0	0.20000E-01	0.19970E-01	0.29542E-04	0.15	1.80370E-02	2.19039E-02	3.86693E-03	19.36
17	1348.0	0.19700E-01	0.19970E-01	-0.26972E-03	-1.35	1.80298E-02	2.19096E-02	3.87974E-03	19.43
18	1346.0	0.19600E-01	0.19971E-01	-0.37121E-03	-1.86	1.80266E-02	2.19158E-02	3.88921E-03	19.47
19	1347.0	0.19900E-01	0.19970E-01	-0.70458E-04	-0.35	1.80343E-02	2.19066E-02	3.87237E-03	19.39
20	1347.0	0.19500E-01	0.19970E-01	-0.47046E-03	-2.36	1.80249E-02	2.19160E-02	3.89115E-03	19.48
21	1295.0	0.22400E-01	0.20266E-01	0.21344E-02	10.53	1.86559E-02	2.18754E-02	3.21952E-03	15.89
22	1283.0	0.21500E-01	0.20288E-01	-0.12117E-02	5.97	1.86500E-02	2.19267E-02	3.27677E-03	16.15
23	1284.0	0.20900E-01	0.20286E-01	0.61364E-03	3.02	1.86374E-02	2.19353E-02	3.29787E-03	16.26
24	1282.0	0.21100E-01	0.20290E-01	0.80967E-03	3.99	1.86433E-02	2.19373E-02	3.29398E-03	16.23
25	1284.0	0.20900E-01	0.20286E-01	0.61364E-03	3.02	1.86374E-02	2.19353E-02	3.29787E-03	16.26

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CASE NUMBER - 1

INITIAL GUESS FOR BETA(1) = 1.485000E-02 , BETA(2) = 0.704600, BETA(3) = 5.710000E-13, BETA(4) = 300.000

INITIAL SUM OF ERRORS SQUARED BASED ON GUESS FOR BETA VALUES = 1.02747

IMPROVED SUM OF ERRORS SQUARED BASED ON 21 ITERATIONS = 0.995780

BETA(1) = 1.524082E-02 , BETA(2) = 0.970194, BETA(3) = 5.841303E-13, BETA(4) = 360.240

***** YF OLDE RESIDUAL ANALYSIS *****

SUM OF THE RESIDUALS = 9.014252E-02

MAXIMUM AND MINIMUM RESIDUAL VALUE = 6.621418E-03 -3.460082E-03

DURBIN WATSON STATISTIC = 0.288271

RUNS = 49(198 9)

SKEWNESS = 1.02208E 000 1.22629E-01)

KURTOSIS = 1.75294 0.24465)

71-72

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