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CALCULATED THERMAL CONDUCTIVITIES OF
He-CO₂, He-Ne, AND He-N₂ MIXTURES.

SUPERSEDES PORTIONS OF HW-21741

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July 20, 1953

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

Operated for the Atomic Energy Commission by the
General Electric Company under Contract #W-31-109-Eng-52

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CALCULATED THERMAL CONDUCTIVITIES OF
He-CO₂, He-Ne, AND He-N₂ MIXTURES.

SUPERSEDES PORTIONS OF HW-21741

INTRODUCTION

Using the modified equation of Wassiljewa, earlier calculations have been made of the thermal conductivities of various gaseous mixtures as a function of temperature and composition⁽¹⁾. An attempt at experimental verification of the values by personnel in the Graphite Development Sub-Unit resulted in finding rather large discrepancies in mixtures involving helium as a component. The reason for a major portion of the discrepancy has been found by personnel in the Heat Transfer Sub-Unit, who pointed out that the value for the Sutherland constant of helium as used in the original calculations was in error. For most gases, the value of the Sutherland constant is approximately 1.5 times the boiling temperature at one atmosphere, but for helium the Sutherland constant departs from this value and is approximately equal to 79°K. The values of the thermal conductivities of helium-carbon dioxide, helium-neon, and helium-nitrogen mixtures have been recalculated on the basis of the correct Sutherland constant, and also certain other minor corrections have been made.

It is the purpose of this document to present the corrected results. These results are in close agreement with the experimental determinations which have been completed to the present time.

SUMMARY

In HW-21741, an erroneous value for the Sutherland constant for helium was used in the modified Wassiljewa formula for the calculation of the thermal conductivity of the He-CO₂, He-Ne, and He-N₂. The

(1) J. M. Wright, "Calculated Thermal Conductivities of Pure Gases and Gaseous Mixtures at Elevated Temperatures", HW-21741, July 18, 1951.

thermal conductivities of these mixtures have been recalculated on the basis of the correct Sutherland constant and are in agreement with known experimental values. The present results supersede those published in HW-21741.

DISCUSSION OF METHOD

The modified equation of Wassiljewa was employed to calculate the thermal conductivities of He-CO₂, He-Ne, and He-N₂ at various temperatures. Calculations using this equation were found by Lindsay and Bromley⁽²⁾ to give an average deviation of 1.9 per cent from the experimental points for sixteen gas pairs at 0°C. The equation is:

$$K_m = \frac{K_i}{1 + \frac{X_j}{X_i} A_{ij}} + \frac{K_j}{1 + \frac{X_i}{X_j} A_{ji}}$$

$$A_{ij} = 1/4 \left\{ 1 + \left[\frac{\eta_i}{\eta_j} \left(\frac{M_j}{M_i} \right)^{3/4} \left(\frac{1 + \frac{S_i}{T}}{1 + \frac{S_j}{T}} \right)^{1/2} \right]^2 \left(\frac{\sqrt{S_i S_j}}{1 + \frac{S_i}{T}} \right) \right\}$$

in which K is the thermal conductivity (cgs units), η is the viscosity, S is the Sutherland constant, T is the absolute temperature, and X the mole fraction of the gaseous components. Subscripts i and j stand for components i and j respectively. The values for the thermal conductivities of the pure components were found by the Eucken equation⁽³⁾:

$$K_T = 1/4 \left[9 (C_p/C_v) - 5 \right] \eta C_v$$

C_p and C_v being the specific heat at constant pressure and volume respectively and η the viscosity, all at the temperature T°K.

(2) A. L. Lindsay and L. A. Bromley, "Thermal Conductivity of Gas Mixtures", UCRL-461, September 28, 1949.

(3) A. Eucken, Phys. Zeitschr., 14, 324-332 (1913).

The results and quantities used in calculations are presented in tabular and graphical form.

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TABLE I
VISCOSITIES

<u>GAS</u>	<u>Viscosity (cgs units)</u>	<u>Applicable Over</u> <u>Temperatures</u> <u>Range (°K)</u>	<u>Average</u> <u>Error</u> <u>(%)</u>
Helium ⁽¹⁾	$2.79 \times 10^{-6} T \left[(T/5.3)^{3/4} + (T/5.3)^{-3/4} \right]^{-0.470}$	15 to 1090	0.8
Carbon Dioxide ⁽¹⁾	$(15.52 \times 10^{-6} T^{3/2}) / (T + 233)$	175 to 1325	1.0
Neon ⁽²⁾	$(11.08 \times 10^{-6} T^{0.6}) / (1 + 20/T)$	293 to 523	1.0
Nitrogen ⁽¹⁾	$(13.85 \times 10^{-6} T^{3/2}) / (1 + 102)$	82 to 1098	0.4

(1) Licht and Stechert, J. Phys. Colloid Chem 48 23-47 (1944)

(2) Trantz and Binkele, Ann. Physik 5, 561-80 (1930)

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TABLE II
CALCULATED VISCOSITIES

<u>Gas</u>	<u>$\eta \times 10^6$ at 273°K</u>	<u>$\eta \times 10^6$ at 400°K</u>	<u>$\eta \times 10^6$ at 600°K</u>	<u>$\eta \times 10^6$ at 800°K</u>
He	189	244	316	381
CO ₂	138	196	275	330
Ne	299	384	499	597
N ₂	166	221	291	338

TABLE III
VALUES FOR A_{ij} AND A_{ji}

	<u>Helium-Carbon Dioxide</u>		<u>Helium-Neon</u>		<u>Helium-Nitrogen</u>	
	<u>A_{ij}</u>	<u>A_{ji}</u>	<u>A_{ij}</u>	<u>A_{ji}</u>	<u>A_{ji}</u>	<u>A_{ji}</u>
273°K	3.647	0.442	1.519	0.713	2.525	0.516
400°K	3.430	0.456	1.521	0.710	2.488	0.523
600°K	3.320	0.469	1.515	0.710	2.455	0.5287
800°K	3.274	0.470	1.523	0.708	2.544	0.5234

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TABLE IV
CALCULATED THERMAL CONDUCTIVITIES

HELIUM-NITROGEN

Mole Fraction Helium	$k \times 10^5$ at 273°K	$k \times 10^5$ at 400°K	$k \times 10^5$ at 600°K	$k \times 10^5$ at 800°K
0	5.6	7.67	10.4	12.9
0.25	8.9	11.9	15.9	19.2
0.50	13.7	18.0	23.8	28.5
0.75	21.4	27.7	36.3	43.3
1.00	35.3	45.2	58.7	70.8

HELIUM-NEON

Mole Fraction Helium	$k \times 10^5$ at 273°K	$k \times 10^5$ at 400°K	$k \times 10^5$ at 600°K	$k \times 10^5$ at 800°K
0	11.0	14.2	18.4	22.0
0.25	15.3	19.6	25.4	30.5
0.50	20.5	26.2	34.1	41.0
0.75	27.0	34.5	44.9	54.0
1.00	35.3	45.2	58.7	70.8

HELIUM-CARBON DIOXIDE

Mole Fraction Helium	$k \times 10^5$ at 273°K	$k \times 10^5$ at 400°K	$k \times 10^5$ at 600°K	$k \times 10^5$ at 800°K
0	3.32	6.13	9.53	12.3
0.25	5.85	9.32	13.8	17.2
0.50	9.90	14.4	20.1	30.0 24.9
0.75	17.3	23.1	31.4	39.0
1.00	35.3	45.2	58.7	70.8

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FIGURE 1

CALCULATED THERMAL CONDUCTIVITIES OF HELIUM-CARBON DIOXIDE MIXTURES

FIGURE 2
CALCULATED THERMAL CONDUCTIVITIES OF HELIUM-NEON
MIXTURES

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FIGURE 3

CALCULATED THERMAL CONDUCTIVITIES OF HELIUM-NITROGEN MIXTURES

ABSTRACT

In HW-21741, an erroneous value for the Sutherland constant of helium was used in the calculation of thermal conductivity values for He-CO₂, He-Ne, and He-N₂ mixtures. Using the correct value the thermal conductivities of the mixtures have been recalculated for 273°K, 400°K, 600°K, and 800°K. The corrected values supersede those published in HW-21741.

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