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SUBJECT: Thermal Conductivity of Beryllium Literature Survey

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THERMAL CONDUCTIVITY OF BERYLLIUM LITERATURE SURVEY

Lewis[1] in 1929 determined the thermal conductivity of beryllium metal for the first time. He found a conductivity of 56 Btu/hr-ft-°F at -176°C, 95 at 9.4°C, and 123 at 190.4°C. The next measurement reported in the open literature on the thermal conductivity of beryllium was by Powell[2] in 1953. He obtained data over the temperature range 50°C - 400°C, and in one case to as high as 700°C. Measurements were also made by Grenell, Linebrink, and Johnson[3] at Battelle Memorial Institute in 1947. Their values are in good agreement with those of Powell.

Powell determined both the electrical and thermal conductivities of five different beryllium samples. From his data he developed an equation expressing the thermal conductivity of beryllium as a function of the absolute temperature and the electrical resistivity over the temperature range 0°C - 400°C.

$$K = \frac{T}{\rho}\left(148.5 - \frac{14390}{T}\right)10^{-8} + \frac{15490}{T} - 8.73$$

where,

K = thermal conductivity, Btu/hr-ft-°F

T = absolute temperature, °K

ρ = electrical resistivity at T, ohm-cm .

The equation is believed to be valid above 400°C. The values predicted by this equation agree to within ± 6% with the experimental thermal conductivities. The first term in the equation gives the electronic contribution

and the last two terms, the lattice contribution to the thermal conductivity. Because heat treatment at 700°C produced increases in the conductivity of the metal, the measurements were made up to a temperature of 300° - 400°C in the as received condition (A.R.). The sample was then heated in an evacuated tube furnace to over 700°C and the conductivities redetermined on the heat treated samples (H.T.). Table 1 and Figure 1 show the thermal conductivities determined by Powell.

TABLE 1

POWELL'S DATA ON THE THERMAL CONDUCTIVITY OF BERYLLIUM

Btu/hr-ft-°F

Temp. °C	Sample II		Sample IV		Sample V		Sample VI		Sample XI	
	A.R.	H.T.	A.R.	H.T.	A.R.	H.T.	A.R.	H.T.	A.R.	H.T.
50	81.5	101.7	78.0	91.3	90.2	104.0	100.0	112.7	104.6	111.5
100	75.1	89.6	72.8	83.2	83.2	93.0	90.7	98.3	94.2	98.3
200	65.3	75.7	64.7	72.8	74.0	78.0	78.6	80.9	80.9	82.6
300	60.1	67.6	60.1	65.3	67.0	69.9	71.1	72.2	72.2	73.4
400			56.1	59.5		64.2	65.3	65.3		67.6
500						59.5				
600						54.9				
700						49.7				

II A bar machined from a drill cast bar prepared from the Brush Beryllium Company's crude reactor product. Density 1.84(2).

IV A bar machined from a drill cast bar prepared from German flake beryllium. Density 1.82(3).

V Same as II, different dimensions. Density 1.84.

VI A bar prepared by the sintering process of American G. E. C. Density 1.83.

XI Process Q Beryllium. Density 1.86(5).

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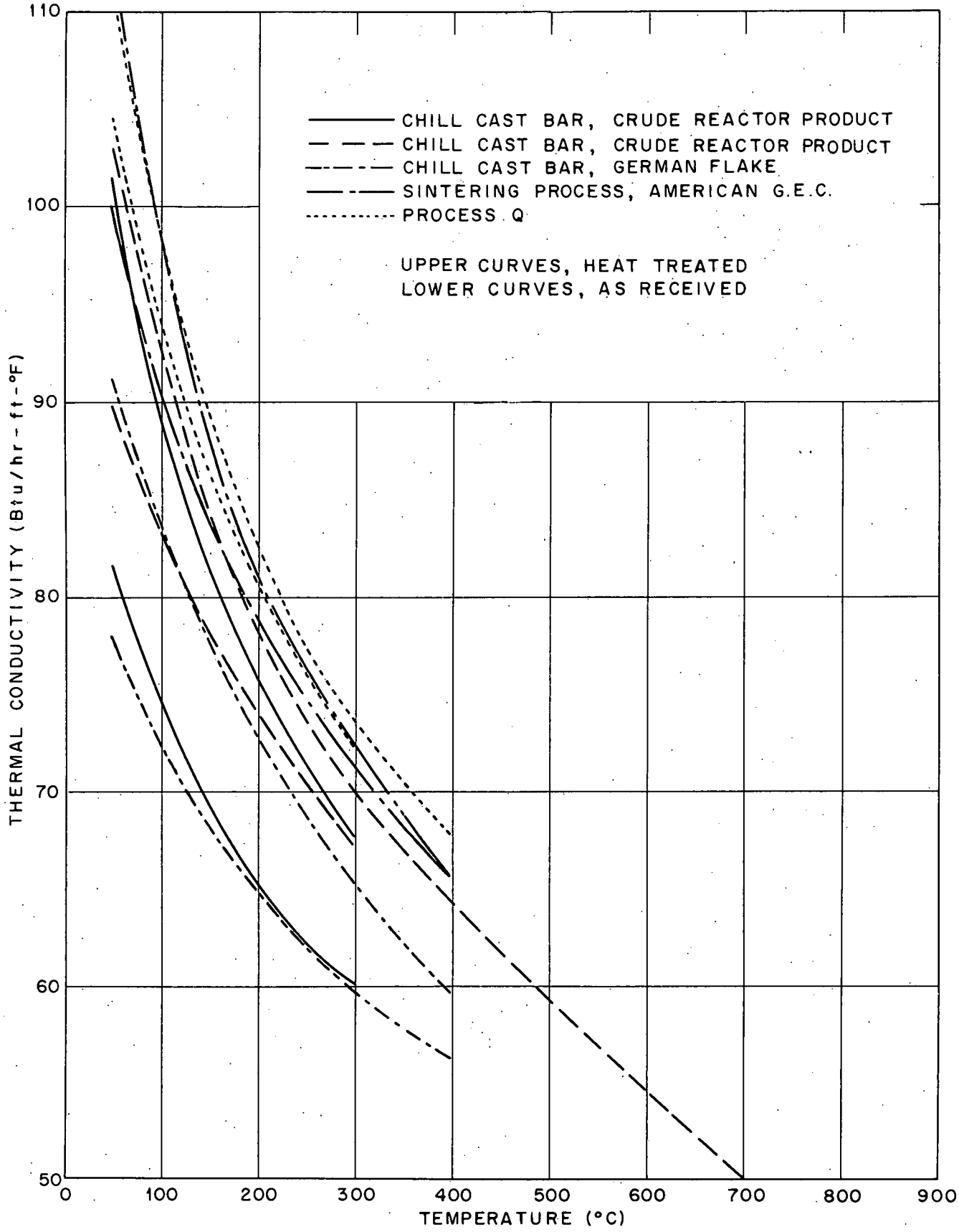

Fig. 1. Thermal Conductitiy – Beryllium (R.W. Powell, Phil. Mag. 44, 645 (1953)

At the Battelle Memorial Institute, Grenell, Linebrink, and Johnson determined the thermal conductivities of two samples of beryllium. Sample R-1 was extruded from vacuum cast metal and sample Y-1 was extruded from flake metal. The vacuum cast metal had a slightly higher conductivity. Their results are shown in Table 2 and Figure 2. In this figure a typical determination by Powell is shown for comparative purposes.

TABLE 2

GRENELL, LINEBRINK, AND JOHNSON DATA
ON THE THERMAL CONDUCTIVITY OF BERYLLIUM

Temperature °C	Vacuum Cast Metal Conductivity (Btu/hr-ft-°F) Run 1	Run 2	Run 3
224	76.3		
273	73.4		
326	69.9		
327		72.2	69.9
378	62.4		
401		69.9	
403			65.9
480		61.8	
483			61.8
564		63.0	
566			61.3
	Flake Metal		
209	72.2		
252	71.1		
296	68.8		
342	66.5		
345		63.6	
417		61.3	
493		57.2	
573		54.3	

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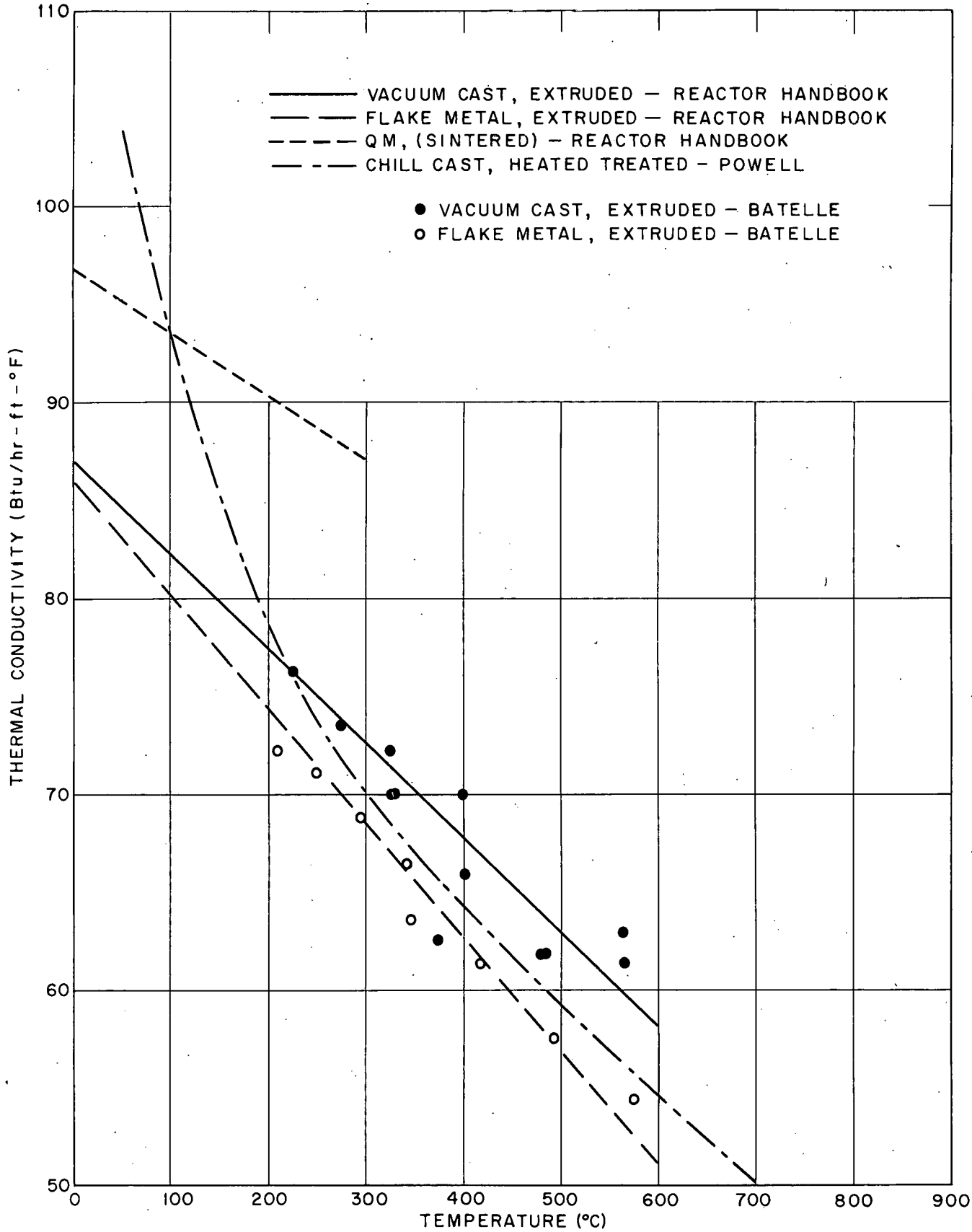

Fig. 2. Thermal Conductivity – Beryllium.

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Data given in Reactor Handbook: Materials[4] are shown in Table 3 and Figure 2. The original references were not given. The first two columns agree with the work at Battelle. Except for the early work of Lewis the QM material above 150°C has the highest conductivity of any beryllium sample tested.

TABLE 3

THERMAL CONDUCTIVITY OF BERYLLIUM
AS GIVEN IN REACTOR HANDBOOK: MATERIALS
Btu/hr-ft-°F

Temperature °C	Vacuum Cast Extruded	Flake Extruded	QM
0°	87	86	97
100°	82	80	93
200°	77	74	91
300°	73	68	87
400°	68	63	
500°	63	57	
600°	58	51	

Room temperature data are given in other references such as Hoyt's "Metal Data" and "Metal Handbook." The values agree closely with the data of Lewis.

The data obtained by Powell and by Grenell, Linebrink, and Johnson show good agreement. It is recommended that their values for the thermal conductivities be used. Since the values obtained by Lewis differ considerably

from the more recent data, it is believed that the determination by Lewis is in error and his values should not be used. If the electrical conductivity of a given sample of beryllium is known or easily determined experimentally, a better estimate of its thermal conductivity could be obtained by using the formula developed by Powell.

REFERENCES

1. E. J. Lewis, Physical Reviews 34, 1575, (1929).

2. R. W. Powell, Philosophical Magazine 44, 645, (1953).

3. L. H. Grenell, O. L. Linebrink, K. L. Johnson, M-3476.

4. Reactor Handbook: Materials, U. S. Atomic Energy Commission, McGraw-Hill (1955), p. 60.