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To: File
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Subject: COOLING HOLE DISTRIBUTION FOR REACTOR REFLECTORS

Date: September 3, 1952

SUMMARY

In the reflector surrounding the core of a nuclear reactor heat generation occurs. In order to keep the thermal stresses within allowable limits or safe guard the reflector from damage, coolant holes must be so distributed as to limit the reflector temperature. Contained in this memo are a series of plots by which the hole distribution can be obtained for a given set of operating conditions for BeO, Be, graphite and BeO-glass.

BASIS FOR SOLVING THE PROBLEM

Cooling holes are to be located in a pattern in a heat-generating solid. The coolant passages are assumed to be cylindrical in shape and are placed on an equilateral triangular pitch. The heat-generating solid can then be broken up into a network of hexagons surrounding each coolant passage.

The hexagonal solid can be approximated by a cylinder whose volume equals the volume of the hexagon. If the heat generation rate in the solid q and thermal conductivity k of the solid are assumed to be independent of time, Poisson's equation in cylindrical coordinates takes the form:

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$$\frac{1}{r} \frac{d}{dr} \left(r \frac{dT}{dr} \right) + \frac{q}{k} = 0$$

where r = radius

T = temperature

k = thermal conductivity

q = heat generation rate per unit volume.

If one takes for boundary conditions the constants $r = a$ at the inner boundary and $dT/dr = 0$ at $r = \beta$ the outer boundary, the solution is given in the form:

$$\Delta T = \frac{q}{4k} \left[\beta^2 \ln \left(\frac{r}{a} \right)^2 + a^2 - r^2 \right]$$

where ΔT = temperature difference between the points $r = \beta$ and $r = a$.

The outer radius β is related to the radius b of a cylinder which circumscribes the hexagon by the formula

$$\beta = \left[\frac{3\sqrt{3}}{2\pi} \right]^{1/2} b.$$

Substituting this expression in the equation above, eliminating β and rearranging yields:

$$\frac{k\Delta T}{b^2 q} = 0.207 \left[\ln \left(\frac{b}{a} \right)^2 + 1.21 \left(\frac{a}{b} \right)^2 - 1.188 \right]$$

This equation is plotted as $\frac{k\Delta T}{b^2q}$ versus b/a in Figure 1.

In Figure 2 $\frac{k\Delta T}{q}$ is plotted versus b/a for several selected appropriate values for b . In Figures 3 through 6, $\frac{\Delta T}{q}$ is plotted versus b/a for several selected values of b for BeO, Be, graphite and BeO-glass for a range of temperatures and conductivities as shown.

In order to facilitate the ready use of these curves the following units have been employed.

$$k = \text{watts/cm}^2 \text{ } ^\circ\text{C/cm.}$$

$$q = \text{watts/cc}$$

$$a = \text{cm}$$

$$b = \text{cm}$$

$$\Delta T = ^\circ\text{C.}$$

REFERENCES

1. Fend, F. A., Bareddy, E. M., and Bell, J. C., "An Approximate Calculation of the Temperature Distribution Surrounding Coolant Holes in a Heat-Generating Solid", Battelle Memorial Institute Report No. BMI-T-42, Oct. 25, 1950.

FIGURE 1

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FIGURE 2

5

EUBENE DIETZGEN CO.
MADE IN U.S.A.
NO. 340R-LS10 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC - 3 CYCLES X 70 DIVISIONS

FIGURE 3 6

1000

Coolant Hole Distribution for BeO

(Thermal Conductivity Data Taken From NYC-501)

T °C.	k watts/cm ² °C/cm
100	1.715
500	0.523
1000	0.1755

b = 10 cm.
T = 1000°C.

b = 10 cm.
T = 500°C.

b = 5 cm.
T = 1000°C.

b = 10 cm.
T = 1000°C.

b = 5 cm.
T = 500°C.

b = 2 cm.
T = 1000°C.

b = 5 cm.
T = 1000°C.

b = 2 cm.
T = 500°C.

b = 1 cm.
T = 1000°C.

b = 2 cm.
T = 1000°C.

b = 1 cm.
T = 500°C.

b = 1 cm.
T = 1000°C.

$\frac{\Delta T}{\sigma}$

b/a

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FIGURE 4 7

Coolant Hole Distribution for Be

(Thermal Conductivity Employed was the Mean of Data Taken From ORNL-973 and NEPA 1015 RMR 57.)

T °C.	k watts/cm. 2oc./cm.
100	1.6
500	1.52
1000	1.04

11000

FIGURE 5 8

Coolant Hole Distribution for Graphite

(Thermal Conductivity Data for Grade GS Stock
Taken from National Carbon Company Report.)

T °C.	k watts/cm. ² °C./cm.
100	1.72
500	0.517
1000	0.254

FIGURE 6

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Coolant Side Distribution for BeO-Glass