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FROM: F. W. Albaugh

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HANFORD STUDIES EXECUTED FOR THE USAEC-AECL COOPERATIVE PROGRAM
ON DEVELOPMENT OF HEAVY WATER MODERATED POWER REACTORS
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11
130

MONTHLY PROGRESS REPORT
HEAT TRANSFER AND FLUID FLOW STUDIES
USAEC-AECL COOPERATIVE PROGRAM
December, 1964

J. M. Batch and G. M. Hesson

Fog-Cooling of 19-Rod Bundles

When 19-rod bundles are cooled with a steam-water mixture, the heat transfer conditions depend on the amount of mixing that occurs between the various flow channels formed by the 19 rods. In most of the arrangements used for placing the 19 rods in round flow tubes, imbalances exist between mass flow (lb/hr) and heat transfer (Btu/hr) throughout the bundle and the enthalpy of the coolant is considerably higher than average in some of the internal flow channels. This results in boiling burnout occurring at lower heat fluxes than would be anticipated when based on bulk flow conditions unless interchannel mixing occurs.

An accurate calculation of interchannel mixing during two-phase flow is not possible at the present time. However, a knowledge of mixing is required to allow prediction and correlation of boiling burnout in 19-rod bundles. Therefore, a brief study was undertaken to obtain some estimates of fluid mixing in multirod bundles at burnout conditions by comparing burnout data obtained at Hanford with data obtained at other sites. The results of this study are being distributed as HW-84525 and only a summary will be presented here.

The burnout data obtained at Hanford with 19-rod bundles were compared with data obtained by General Electric Company at San Jose, Columbia University, and the United Kingdom Atomic Energy Authority with various types of multirod test sections. Inspection of these data reveals large differences for some configurations when comparison is made on plots of burnout heat flux versus bulk outlet enthalpy with mass velocity and rod spacing as parameters. It was found that good agreement existed for those multirod configurations which had large rod spacings (greater than 0.074-in.) so that interchannel mixing was not restricted and/or in which heat flux distribution had been adjusted so that there was small variation in local enthalpy even under poor mixing conditions.

Those data where there was good agreement were used to establish a series of burnout curves in which mass velocity and rod spacing were parameters. Mixing factors were then determined for those data which deviated from the established base curves. The deviating data were mainly for those configurations which had small rod spacings or unsatisfactory heat flux distributions, or both.

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A semi-theoretical correlation of enthalpy as influenced by mixing was obtained for 19-rod bundles as follows:

$$Y = \frac{1}{KL} \left(1 - e^{-KL} \right) + 0.25 (x'_c - 0.5)$$

and

$$K = 0.6 (1 - e^{-36s}) \left(\frac{G}{10^6} \right)^{1.8}$$

where

$$Y = \frac{\Delta H_{LOC} - 1}{\Delta H_{NM} - 1} \quad (\text{for the hottest channel})$$

L = length of heated section

K = factor proportional to rate of interchannel mixing

x'_c = fractional length where boiling begins in the cold channels adjacent to the hottest channel

ΔH_{LOC} = an enthalpy change of fluid in a flow channel under mixing conditions

ΔH_{NM} = enthalpy change of fluid in a flow channel under non-mixing conditions

s = rod spacing, in.

G = bulk mass velocity, lb/(hr)(sq ft).

Limitations:

1. Applicable to 19-rod bundles, with vertical or horizontal orientation, either "wire wraps" or "warts" for rod spacers.

2. Mass velocities greater than 1.0×10^6 lb/(hr)(sq ft).

These equations were used to calculate local exit enthalpies for the hottest channels and give considerable improvement to the agreement among the experimental data.

The correlation provides an approximate method of calculating local enthalpies in the hottest channels of multirod bundles and therefore a means of determining if burnout conditions exist for a given flow rate, heat flux, and inlet enthalpy.

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The burnout curves established in this work show that burnout heat flux varies inversely as rod spacing and also inversely as mass velocity over the ranges studied in the investigations. The latter relation holds below burnout heat fluxes of 0.7 to 1.0×10^6 Btu/(hr)(sq ft).

It is concluded from the study that as the rod spacing is decreased, the flow mixing between channels is restricted and causes low burnout heat fluxes due to high local values of the coolant enthalpy.