MAXIMUM WAKE TEMPERATURE AND NUSSELT NUMBER BEHIND BLOCKAGES IN SODIUM-COOLED BUNDLES*

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Two important correlations have been obtained to calculate the maximum coolant temperature and the Nusselt number in the wake (the flow recirculating zone) downstream of blockages in 19-pin sodium-cooled bundles. These correlations can be applied to predict the maximum temperature rise and the average heat transfer coefficient behind small non-heat-generating blockages in the fuel assemblies of the FFTF and the CRBR for a wide range of flow and power conditions.

Experiments with partial blockages in simulated LMFBR fuel assemblies have been performed at the THORS facility (formerly called FFM)[1] of the Oak Ridge National Laboratory. Nineteen-pin sodium-cooled bundles were used, which had the same pin diameter and pitch as the CRBR and the FFTF fuel assemblies. Two kinds of the blockages were investigated: (1) a 6-channel central blockage (bundles 3A and 3B)[1], and (2) a 14-channel edge blockage (bundles 5B and 5B-d)[2,3] for which the blockage was either held flush with the duct wall or intentionally slightly displaced from the wall. The correlations are derived from temperature measurements for single-phase

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flow in the wake with various combinations of the flows and powers.

Let D_h = hydraulic diameter = 3.03 mm (0.1194 in.) for an internal channel in the FFTF and CRBR fuel assemblies, K = sodium thermal conductivity, Nu = Nusselt number in the wake = $q'' D_h/(K(T_w - T_{wk}))$, q' = power per unit length per pin in the wake, q" = heat flux in the wake ($= q'/(\pi d)$, where d = pin diameter), Re = Reynolds number = $U D_h/\nu$, Re_∞ = modified Reynolds number = $Re/(1 - \beta)$, T_B = bulk mean sodium temperature at the blockage, T_{max} = maximum wake temperature downstream of the blockage, T_w = average temperature on the pin surface in the wake, T_{wk} = average sodium temperature in the wake, U = mean sodium velocity in the bundle, ν = kinematic viscosity, and β = blocked fraction of the flow area in the bundle (β = 0.12 for the 6-channel central blockage in bundles 3A and 3B, and β = 0.34 for the 14-channel edge blockage in bundles 5B and 5B-d).

Figure 1 shows the dimensionless maximum wake temperature vs the modified Reynolds number. A straight line fits these data points fairly well and has the following form:

$$K\,(T_{max} - T_B)/q' = 1970\ Re_\infty^{-0.79} \qquad (1)$$

The Nusselt number vs the modified Reynolds number is shown in Fig. 2. Similarly, a straight line can be used to fit the data. This gives

$$Nu = 0.0043\ Re_\infty^{0.55} \qquad (2)$$

It should be noted that from Eq. (1) a 14-channel blockage, made of non-heat-generating material, will not result in sodium boiling in the FFTF or the CRBR fuel assemblies at the design conditions.

For a small non-heat-generating blockage in the fuel assemblies of the FFTF or the CRBR, as a first approximation, the maximum temperature rise and the heat transfer coefficient in the wake behind the blockage can be easily determined from the correlations obtained in this study (Eqs.(1) and (2) respectively).

REFERENCES

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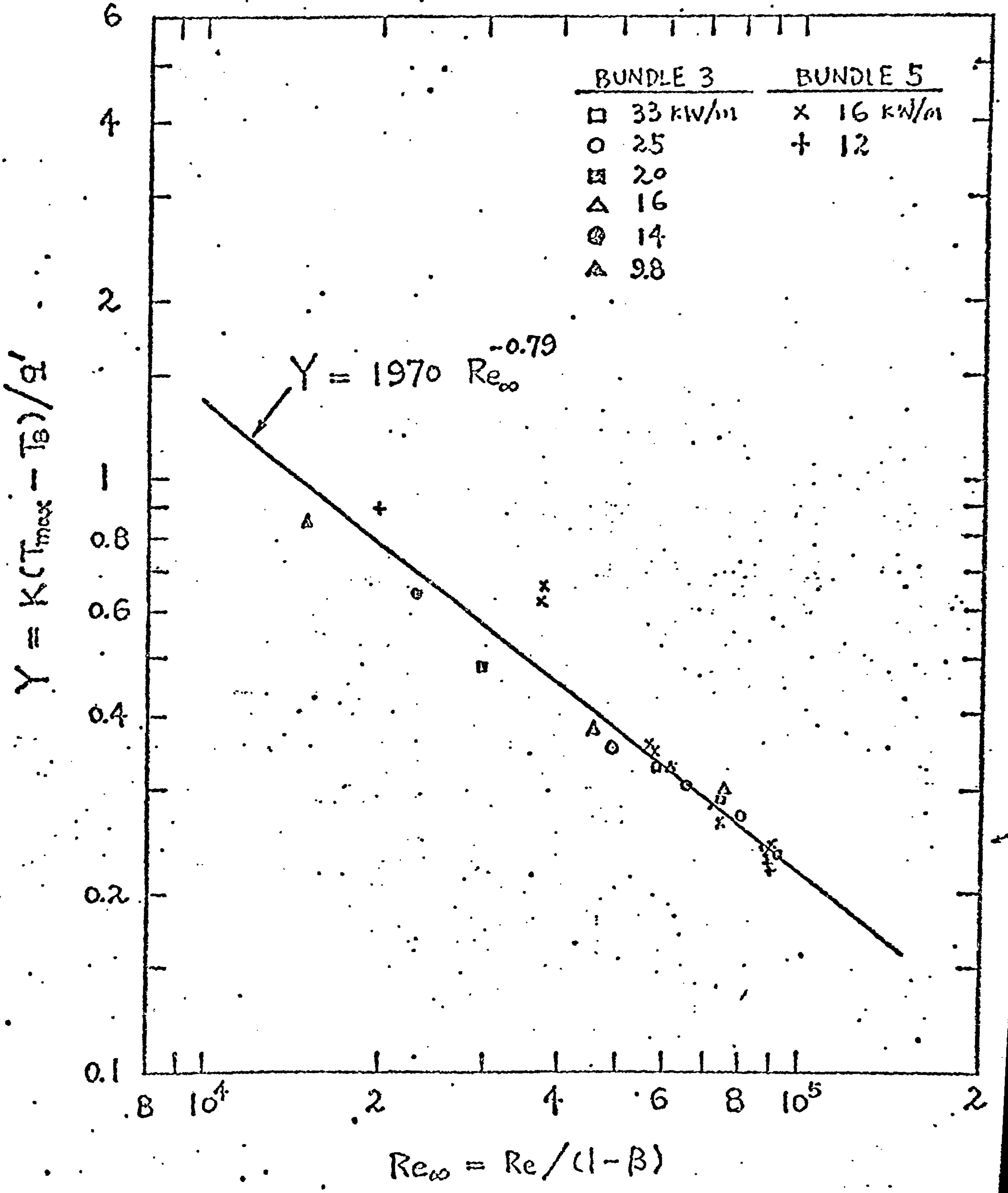

Fig. 1. Dimensionless maximum temperature rise in the wake behind a 6-cha internal blockage (THORS bundles 3A & 3B) and in the wake behind a 14-c edge blockage (bundles 5B & 5B-d) in a 19-pin sodium-cooled bundl

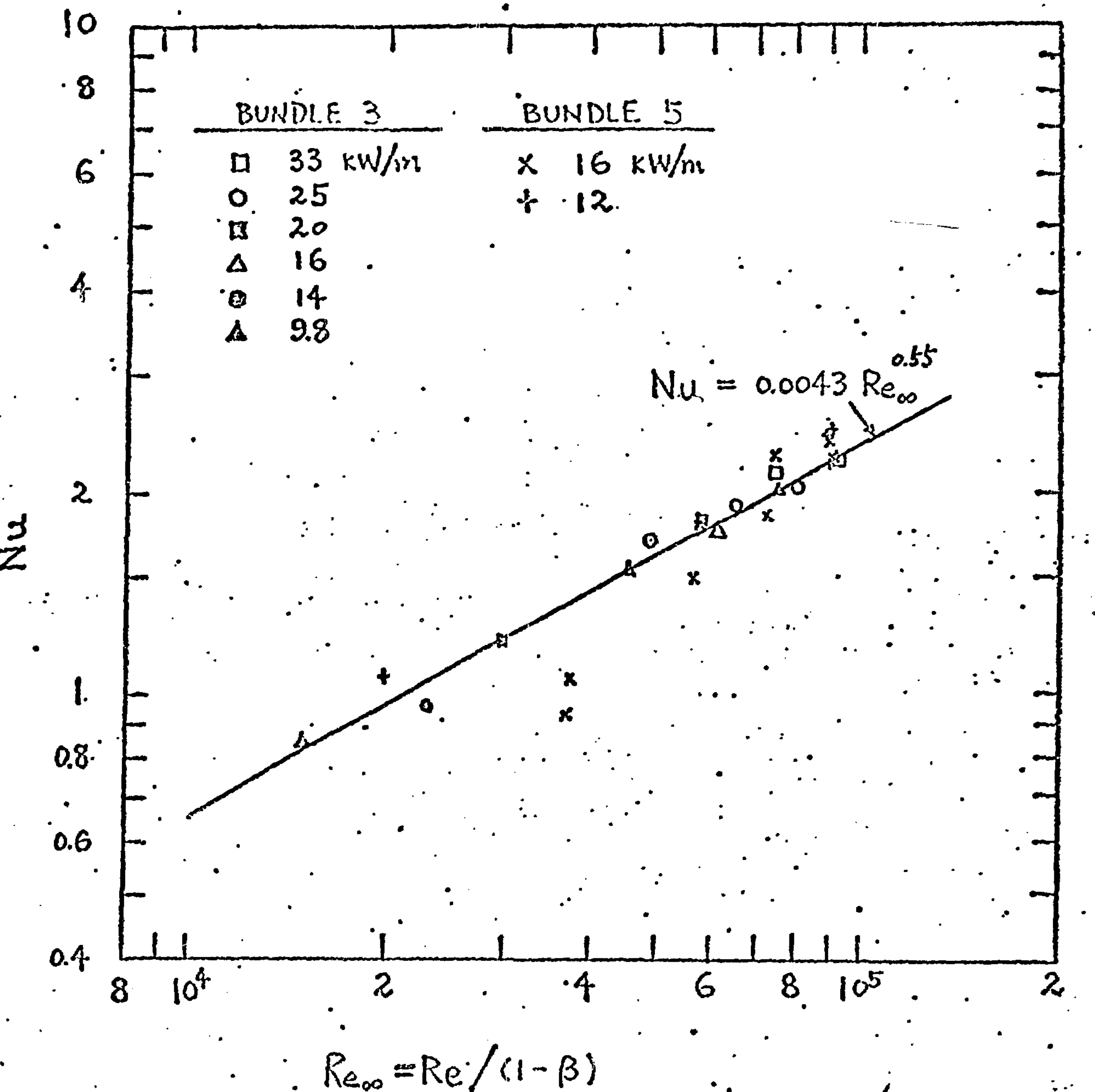

Fig. 2. Nusselt number for heat transfer in the wake behind a 6-channel internal blockage (THORS bundles 3A & 3B) and in the wake behind a 14-channel edge blockage (bundles 5B & 5B-d) in a 19-pin sodium-cooled bundle.