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A note on pressure drops through boiler tube banks

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SUBJECT A NOTE ON PRESSURE DROPS THROUGH BOILER TUBE BANKS

PREPARED BY E. H. Dudgeon
 I. R. G. Lowe

ISSUED TO

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A study of the flow in a 1/12 scale model of a waste heat boiler resulted in an interesting observation on the pressure drop through boiler tube banks, Reference 12. Because of the danger of fouling, the transverse or crossflow pitch to diameter ratio was unusually large for the first two tube banks of the waste heat boiler being studied. Initial testing of the model indicated that the pressure drop across the first tube bank was markedly different from the pressure drop as calculated, using an extrapolation of the classical correlation by Jakob (Reference 1).

A glance at modern heat transfer texts, References 2 to 5 for example, shows that the Jakob equation is still the method of choice for tube bank pressure drop calculations. The Jakob equation was based on work by Grimison, Reference 6, who correlated experiments, References 7 and 8, in which the maximum transverse pitch to diameter ratio was 3. In the model under test the ratio was 8.67. (It is felt that a trend to large ratios will be seen as more waste heat boilers are built to be fed by dirty flue gas such as encountered in the pyrometallurgical industries.) Consequently our waste heat boiler model was modified slightly to allow a determination of the pressure loss coefficient for the tube bank and to compare the coefficient not only with the prediction of the Jakob equation but also with the more recent correlations due to Gram, Mackey and Monroe, Reference 9, and due to Kuznetsov, Reference 10, as reported in Reference 11. The correlation of Reference 9 covered transverse pitch ratios up to 6 while that of Reference 10 went up to 9.5.

The test arrangement for the waste heat boiler model is described in Reference 12. A bellmouth entry replaced the modelled entry duct to the test section and the bellmouth was covered with window screening to smooth the air flow. The tube bank under test was a matrix 16 tubes wide by 10 tubes deep. As previously mentioned the transverse pitch to diameter ratio was 8.67 and the stream-wise pitch to diameter ratio was 2.5. The tubes were plain and the rows were in line, i.e. not staggered. A second tube bank 14 wide by 7 deep with a transverse pitch to diameter ratio of 5 and longitudinal ratio of 2.5 was also tested to provide an intermediate point which was within the range of ratios covered by Reference 9. Room air was drawn through the model by a 93 kw exhaust fan and the flowrate was measured by a 15 mm diameter orifice plate in the exhaust duct.

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Static pressure tappings in the roof and floor of the test section were used along with a modified Kiel-type total-head probe. Pressures were measured by a Betz micromanometer. A total-head traverse upstream of the tube bank was used to confirm the uniformity of the flow in the test area. Several flowrates were tested in the range of tube Reynolds numbers close to the full scale Reynolds number of 1,300. (Tube Reynolds number utilizes the tube diameter and the mean velocity between the tubes.)

Results showed that the tube friction factors were independent of flowrate in the range tested. Figure 1 shows the averaged results for the two pitches tested. Comparisons are made with the Jakob equation as well as with the correlation of Gram, Mackey and Monroe, and that due to Kuznetzov. The Jakob equation was calculated for a tube Reynolds number of 10,000 as recommended in Reference 2. The correlation of Gram, Mackey and Monroe was that for a tube Reynolds number of 2,000 while the Kuznetzov correlation used $Re = 6,000$ the minimum applicable.

It can be seen that at large transverse pitch to diameter ratios the correlations of Gram et al and of Kuznetzov are in good agreement but both are considerably different from an extrapolation of the Jakob equation. Even at lower values of pitch ratio the Jakob equation is still in considerable disagreement with the other two correlations.

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FIGURE 1

