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HYDRAULIC STUDIES TO AID IN DESIGN OF BUMPER FUEL ELEMENTS FOR "O" REACTORS

E. D. Waters

INTRODUCTION

In-reactor tests of self-supported fuel elements in ribless process tubes have shown a significant reduction in hot spot failure incidents. It is believed that the support rails prevent gross fuel element cocking or misalignment which would allow inadequate cooling of a portion of the fuel element. It is reasoned that if similar spacing devices were attached to fuel elements for use in present ribbed tubes, an appreciable reduction in hot spot failures would result. The problem then remains to select suitable spacing devices, hereafter called "bumpers", and to assess the increased energy losses associated with their use.

Efforts to predict the energy losses which may be caused by fuel element support rails or bumpers have been somewhat discouraging. The odd shape of the support rails, which appear something like a close-coupled suitcase handle, preclude the rigorous use of available drag coefficients or contraction-expansion coefficients. Hence, it is necessary to make pressure drop measurements with a fuel element design (size) which is considered to be quite close to meeting the actual pressure-flow requirements. Then the final design is determined in view of these data.

The data of this report were obtained in the 189-D Hydraulics Laboratory to study the hydraulic characteristics of a specific fuel element size in a standard EDF ribbed process tube. The data allow determination of the effect of attaching "bumpers" to this size of fuel element. Although the bumper fuel elements for actual reactor usage will probably be of the I&E type, the elements used in these tests were of solid type in order to eliminate the parameter of hole channel flow which lends itself quite well to analytical correlation. The data will aid in selecting the final fuel element design (size) and should not be interpreted as representing pressure drop or flow rate changes which may result from reactor usage of bumper fuel elements of an ultimate design.

SUMMARY

Laboratory data are presented on Figure I to show the isothermal pressure drop characteristics of solid fuel elements with a 1.442" OD. Data are shown for cases with and without "bumpers" attached to the surface of the elements. It was found that these bumpers, which were made from approximately .023" sheet and had a finished height of about .033", will cause a pressure drop increase of 30 per cent compared to the same fuel element without bumpers in a standard aluminum EDF ribbed process tube.

Analytical prediction of the energy losses associated with these bumpers did not compare well with the experimental data when generally accepted contraction-expansion loss coefficients were used as the basis of calculations. A possible method of correlating data or predicting losses for other sizes of bumpers is suggested.

Data were taken to study briefly the effect of misalignment of bumpers from one fuel element to the next. It was found that careful alignment of the bumpers would not reduce the energy losses more than 1 1/2 per cent compared to the case of having the bumpers intentionally misaligned from one fuel piece to the next.

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DISCUSSION

Two 34-piece charges of standard length solid fuel elements were used in these experiments. The pieces measured 1.440" to 1.443" OD and averaged about 1.442" OD (exclusive of bumpers). One charge had no bumpers attached and was used as a control or comparison charge. The other 34 pieces each had eight bumpers attached (four equally spaced bumpers near each end of the fuel piece). The bumper dimensions are shown in the following sketch.

TYPICAL EACH END OF FUEL ELEMENT

The fuel pieces were charged into a standard ribbed BDF process tube. Static pressure differences were measured between the front nozzle barrel and the end-of-active-section for various isothermal flow rates. The experimental data are shown on Figure I for three different charge conditions: for plain solid fuel elements, for bumper fuel elements with bumpers misaligned, and for bumper elements with bumpers aligned.

From these data, one finds that the bumpers cause about 30 per cent increase in pressure drop over that for the plain solid fuel elements. Using available contraction-expansion loss coefficients (such as Perry's Handbook, p. 388) and using the contraction based on only the tab end of the bumper, one would calculate a ΔP increase of only 13.5%. Using the contraction based on the total projected end area of the bumpers, then the calculated increase of ΔP would be about 18 per cent.

It was found that if a combined contraction-expansion loss of one velocity head change were allowed (based on the flow area at a section through the weld tab portion of the bumper compared to the flow area without bumpers), then a 30 per cent pressure drop increase would be predicted for these bumper fuel elements. There is no good reason for using the "one velocity head change" basis other than it checks rather well for this particular case and may be useful in correlating data for other size bumpers.

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A brief determination of the effect of bumper alignment was made by recording data for two different alignment arrangements. For both cases there was necessarily one bumper between the ribs of the process tube at all times. The "misaligned" case used a repeat pattern of five fuel pieces with the "between rib" bumper of four pieces being alternated first against one rib and then the other with the fifth fuel piece having a bumper centered between the ribs. The "aligned" case was arranged such that the "between rib" bumper was against the same rib for each fuel piece. The fuel elements were all charged by hand.

Comparison of the data for different bumper alignments indicates a maximum difference between the two cases of only about 1.5 percent. The difference is largest for the 50 C condition although the reason for this is not readily apparent. This fact and the fact that the overall accuracy claimed for the data is about 1.2 percent would lead one to the preliminary conclusion that bumper alignment is probably not a significant effect. The effect of alignment will be determined at a later date for the support rails of self-supported fuel elements which take up a larger portion of the annulus area than the bumpers.

SUGGESTION FOR FURTHER STUDY

Although unrelated to the present study, the thought has occurred that a 0.10" spacing between the raised portion of the bumper and the can wall proper may cause some problem from a heat transfer standpoint. It seems hard to grasp the idea that well defined forced convection heat transfer could occur in this thin gap under the bumper. This gap may present a static or reduced liquid velocity region and result in boiling and partial vapor blanketing under the bumper. Since each bumper represents a fuel element surface area $3/16"$ x $1"$, it may result in a "hot spot" on the fuel element similar to that which could result from a uranium-to-jacket bond defect.

This situation should be considered and will be at least briefly studied in the glass test section of the 189-D Heat Transfer Apparatus as time and materials are available.

E. D. Waters

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FIGURE I

PRESSURE DROP COMPARISON DATA
(34 piece charge of 1.442" O.D. solid fuel elements)

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