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A Division of North American Aviation, Inc.

JUL 5 1960

NAA-SR-MEMO-5124

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WRITTEN BY R. J. Begley *		ATOMICS INTERNATIONAL A Division of North American Aviation, Inc. TECHNICAL DATA RECORD	TOR NO. 5124	
SECTION 794			GO 7519	
GROUP 41			LEDGER ACCT. 3621	
UNIT Engineering Measurements			SUB-ACCT. 4000	
APPROVED BY: (SUPERVISOR) J. J. Droher		PROGRAM Advanced SGR	TWR 7778	
OTHER		PROJECT Reactor Operations	DATE April 28, 1960	
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SUBJECT: Hydraulic Tests of the 5-Rod and Dummy SRE Fuel Elements

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I STATEMENT OF PROBLEM

The Th-U fuel loading for the SRE will include a process-tube filter at the bottom of the fuel element and a redesigned orifice-plate assembly which is an integral part of the hanger rod. In addition, 5-rod fuel clusters will be used in the loading. Pressure-flow data are required for this element in order to properly orifice the reactor. Pressure-flow data are also required for dummy fuel elements. To obtain such data the following effort was requested: (1) Measure the pressure drop across a mockup of the 5-rod fuel element, with various orifice sizes in a water loop. (2) Repeat for the dummy fuel element. (3) Convert data to equivalent values for sodium at SRE operating temperatures.

II. SUMMARY OF RESULTS AND RECOMMENDATIONS

Pressure-drop measurements were made across mockups of the 5-rod and dummy fuel elements in a test section installed in the Hallam Hydraulic Loop. The test section was identical to an SRE fuel channel and included simulated upper and lower plenums. Data were obtained using water as a test fluid and were converted to sodium at 750°F which is the arithmetical mean of the process-tube entrance and exit temperatures.

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Figure 1, Page 7, is a photograph of the 5-rod element with blow-ups showing the filter and orifice assembly.

Figure 2, Page 8, is a plot of sodium flow rate versus core pressure drop for the 5-rod fuel element alone and in combination with orifices with various hole sizes. Tests were performed with the orifice plate in both the hot and cold elevations relative to the moderator spacer ring. No differences in flow rate were observed at these two elevations.

Figure 3, Page 9, shows sodium flow rate versus orifice hole size for several core pressure drops for the fuel element. This curve can be used to determine the orifice hole sizes for fuel elements in different radial locations in the reactor.

Figure 4, Page 10, is a plot of pressure-drop versus flow rate for the orifice plates. The water data for this curve were converted to sodium at an outlet temperature of 950°F.

Figure 5, Page 11, is a plot of pressure-drop versus flow rate for the filter located at the bottom of the fuel element. The water data for this curve were converted to sodium at an inlet temperature of 550°F. The open filter contributes from 3.1 to 13% of the total core pressure drop. This curve also shows the effect of obstructions (as a percent of clean flow area through the filter) on the pressure drop.

Figure 6, Page 12, is a curve of the change in core outlet temperature versus percent filter area obstructed for three typical orifice sizes. This curve can serve as an aid in determining when the fuel element should be removed from the reactor and the filter replaced.

Figure 7, Page 13, is a plot of pressure-drop versus flow rate for the dummy fuel element with two sizes of cooling grooves.

III. DESCRIPTION OF EQUIPMENT

Figure 8, Page 14, is a schematic diagram of the hydraulic loop used for these tests. Water, which was heated in the surge tank,

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was circulated through the flow-metering orifice, up through the test section, and returned to the surge tank. The test section was a mockup of the SRE process tube including simulated upper and lower plenums. The lower plenum was simulated by a 7-foot length of 10-in. I.D. stainless steel tubing. Entrance to the process tube was through a mock pedestal-grid plate assembly identical to the SRE configuration. The process tube was simulated by a 10-foot length of 2.810-in. I.D. stainless steel tubing. The exit from the process tube to the upper plenum was through a mockup of the SRE moderator-can spacer which extends two inches into the upper plenum. The upper plenum mockup consisted of a 4-foot length of 10-in. I.D. stainless steel tubing.

Pressure-differential measuring taps were located at the points indicated in Figure 8. Pressure drops between these points were measured with a differential manometer using Meriam #3 (sp. gr. 2.95) or mercury as the manometer fluid. The flow rate was measured with an ASME, flange tapped, square-edged, 1.862-in. diameter orifice plate with an inclined manometer using Meriam #3 as the indicating fluid. The flow was controlled by a by-pass valve across the pump and two throttling valves; one before the flow metering orifice, the other after the test section. The second valve was required to maintain a positive pressure in the upper plenum to preclude boiling of the hot water.

The fuel element was supported by a 5/8-in. diameter hanger rod. A turnbuckle was included on the hanger rod to provide a means for testing the orifice plates at different elevations in the moderator spacer ring.

IV. DISCUSSION

The test orifice plate support member was machined to appropriate dimensions to simulate the effect of thermal expansion upon the annular clearance between the orifice support member and the process tube wall. (Ref. 1, Page 3)

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Elevation of the orifice plate with respect to the moderator spacer ring will vary from channel to channel in the SRE. This variation is due to differences in length of the moderator cans, differences in elevation of the hanger rod support steps in the top shield, and differences in length of the hanger rods. Elevation of the orifice plate will also vary with temperature. The nominal elevation of the fuel element in the hot and cold states was determined from Reference 2. In these hydraulic tests, plus or minus one-half in. was allowed for mechanical differences in elevation for both the hot and cold elevations. No effect on flow rate was observed.

The orifice pressure drop curves plotted in Figure 4 were obtained by subtracting the pressure drop across the orifice section (taps 1 and 2, Figure 7) containing the fuel element with no orifice assembly from the pressure drop across the same section with the fuel element with an orifice plate. This curve therefore indicates the additional pressure drop resulting from adding the orifice assembly to the top of the fuel element. In future SRE tests of different fuel element geometries utilizing these orifice assemblies, data from a hydraulic test of the fuel element without an orifice assembly can be added to the curves in Figure 4 to construct the curves of Figures 2 and 3 for the particular fuel element. The only limitation on this procedure is that the entry conditions to the orifice plate should be similar to the entry conditions for this element. This technique should appreciably lower the time required for performing future hydraulic tests of SRE fuel elements.

The filter pressure drop curves in Figure 5 were obtained by subtracting the pressure drop across the inlet to the fuel element (taps 3 and 4, Figure 7) with no filter attached from the pressure drop across the inlet with the filter attached. This curve therefore shows the additional pressure drop obtained when the filter is added to the fuel element. The open filter pressure drop varies from 0.062 psi at a flow rate of 3 lb per sec to

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0.26 psi at a flow rate of 6 lb per sec. This pressure drop represents from 3.1 to 13% of the total core pressure drop.

To determine the effect on flow rate of filter clogging, the filter flow area was artificially reduced by placing sheet metal cones on the screens. The obstructed areas tested were 25%, 50%, 75%, and 100% of the total filter area. No attempt was made to reduce the area of the annulus between the filter and the process tube wall. The results of these tests are also included in Figure 5. A curve of total core pressure drop versus flow rate for the fuel element with 1/4-in., 7/16-in., and 5/8-in. orifice sizes with the filter with the above listed obstructions was constructed by adding the filter pressure drop to the element with orifice pressure drop. This curve was then cross plotted to yield a plot of flow rate versus filter obstruction for a core pressure drop of 2.0 psi. A curve of the change in core outlet temperature versus filter obstruction is presented in Figure 6. Assumptions enabling the construction of Figure 6 are: (1) channel outlet temperature is directly proportional to the flow rate for constant channel power, (2) the outlet temperature is 950°F when the filter is open. If the channel outlet temperatures are monitored closely, the accumulation of foreign matter on the filter can be determined from this curve. Therefore a program of filter removal can be established.

V. SAMPLE CALCULATIONS

Sample calculations for similar hydraulic tests can be found in Reference 3.

VI. REFERENCES

1. TDR 4776, "Pressure Drop Measurements Across a Mockup of an SRE 7-Rod Fuel Element With an Orifice Plate at the Top," by R. J. Begley, dated December 23, 1959.
2. Unreleased drawing by J. Greenleaf.

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3. TDR 4644, "Pressure Drop Measurements Across a 4-Rod Fuel Element to be Tested in SRE," by R. J. Begley, dated November 5, 1959.
4. Original data for this report are recorded on Pages 47 to 51 in Laboratory Notebook A-082001.

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Figure 1. Photograph of 5-Rod SRE Fuel Element

FIGURE 4
ORIFICE PRESSURE DROP
VS. CHANNEL FLOW RATE

SODIUM TEMPERATURE 950°F
ORIFICE HOLE SIZES NOTED

110 206 SODIUM FLOW RATE, lb/sec

ORIFICE PRESSURE DROP, PSI

FIGURE 5
FILTER PRESSURE DROP
VS CHANNEL FLOW RATE
SODIUM TEMPERATURE 550°F
PERCENT FILTER AREAS OBSTRUCTED
NOTED ON CURVES

Flow Rate, lb/sec

200

0.01

FILTER PRESSURE DROP, PSI

OPEN

25%

50%

75%

100%

FIGURE 6
INCREASE IN CORE OUTLET TEMPERATURE DUE
TO BLOCKING OF THE STRAINER ON THE
5-ROD FUEL ELEMENT

FIGURE 8
SCHEMATIC OF HYDRAULIC LOOP