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WANL-TME-398

June, 1963

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SPECIAL REVIEW FINAL DETERMINATION	Reviewed	Class.	Date
	JRP	u	5-12-82
Class:	u		

DESIGN SIGNIFICANCE OF COMPONENT TESTS

Classification cancelled (or changed to)
by authority of Doc
by H.A.C. TIC, date SEP 10 1973

By:

A. I. Miller
Reactor Analysis

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DESIGN SIGNIFICANCE OF COMPONENT TESTS

1.0 INTRODUCTION

The component test program has been designed to permit a realistic evaluation of critical components and, where necessary, to point the way to design or operational changes which will provide a high level of assurance of a successful power test.

The thermal and fluid flow areas of experimental investigation fall into several categories of generally different character:

- a. Tests to supply data necessary for the sizing of flow control orifices and other impedance devices.
- b. Tests to determine the physical capabilities of critical sections to withstand thermal stresses and hydraulic loads.
- c. Tests to determine distribution of coolant in critical areas.
- d. Tests to determine the effects of self-excited or forced vibrations.
- e. Tests to check the real performance of several critical components.
- f. Tests to provide basic data on heat transfer and fluid flow to permit improvement of analytical techniques.

The exact nature of the tests is outlined in the NRX-A Component Test Program (WANL-TNR-095). The test program outlined therein, is presently underway. Some tests are complete, some partially complete, and others still in the design stage. This report summarizes the results obtained to date from this test program and their design significance.

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2.0 APPLICATION OF TEST DATA

2.1 Tie Rod Hangar, Bushing and Core Flow Tests

The series of tests outlined under Test Specification A-7 of WANL-TNR-095 are largely complete for the present NRX-A design configuration⁽¹⁾. They fall primarily in the category of supplying data necessary for the sizing of flow control orifices and/or other impedance devices. Each can be dealt with separately.

2.1.1 Tie Rod Hangar

The tie rod hangar assembly is located in the core support plate above the core. The geometry of the flow passage is such as to preclude the highly accurate determination of its pressure loss coefficient by purely analytical techniques. This geometry is shown in Figure 1. As can be seen, the flow through the hangar assembly is controlled by 6 drilled slots near the dome end of the hangar. Flow enters from the inlet plenum to the core support plate passes through the 6 slots and then down around the tie rod, cooling it, and then discharges into the core inlet plenum through the pre-load spring.

Test results are plotted in Figure 2 for various slot areas, as pressure loss coefficient versus flow rate. The loss coefficient is based not upon the slot area, but upon the annular area between the tie rod and the holder. This area is the minimum flow area when slots areas greater than 0.048 sq. in. are considered. As can be seen from the plot, as the slot area increases, the relative significance of this resistance decreases until, at the larger flow areas, the loss coefficient becomes that merely of a

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sudden contraction and expansion. This is also shown in Figure 3 where the loss coefficient is plotted as a function of slot area at a constant flow rate.

These test results were used to determine a pressure loss coefficient of 1.4 for the design flow area of 0.141 sq. in. (6 slots, 0.250" by 0.094"). At full power operating conditions of 689 psia and 201 °R at the support plate inlet and a pressure differential of approximately 0.3 psi (corresponds to that across the core support plate), 41 lbs/hr flows through the tie rod hangar assembly. This flow rate has been used to determine the adequacy of the thermal design of the tie rod hangar assembly and the adjacent portions of the top support plate.

2.1.2 Tie Rod Centering Bushing

Coolant is provided to the tie rod channel by means of radially drilled holes in the tie rod centering bushing. The centering bushing fits into the top of the tie rod coolant channel at the core inlet. The upper portion of the bushing is split to allow for tie rod insertion. A tie rod computer program has been set up in such a manner as to give an inlet loss coefficient (i.e., for the centering bushing) for any desired exit temperature and conversely for any inlet loss coefficient will give the exit temperature. The experimental determination of the loss coefficient for the centering bushing was initiated early in the component test program, so that this data would be available to correlate with the tie rod computer program and the centering bushing flow control hole size selected.

Preliminary testing indicated that leakage paths existed which bypassed flow around the flow control orifices in the centering bushing. These leakage paths

were found to be along the shaft, through the split in the bushing, and through the interface between the upper part of the bushing and the bushing body. Tests were performed with these leakage paths open, as assembled, and sealed. Results are plotted in Figure 4 for various hole sizes with all these passages sealed.

This curve shows that there is little effect of hole size in the range investigated. Estimates of the loss coefficient for the leakage case are shown in Figure 5. Here the loss coefficient is based upon the total flow area (i.e., leakage flow areas plus centering bushing hole area). These estimates are still to be corroborated by experiment.

The estimated loss coefficients for the completely unsealed case were corrected to tie rod channel flow area. These values are plotted in Figure 6 as a function of orifice diameter. This data was then correlated with the calculated loss coefficient data from the tie rod computer program in order to size orifices for the centering bushing.

2.1.3 Tie Rod Cone Support

The exit loss coefficient for the tie rod flow channel is due to the flow pattern as it passes through the molybdenum core support. The pressure drop for this portion of the flow passage consists essentially of an entrance loss, a turning loss, and an exit loss. Test results are plotted in Figure 7 for several hole sizes, as a function of mass flow rate.

The design configuration of 12 - 0.059 inch diameter holes has a loss coefficient of 0.98 at high flow rates. Since the experimental loss coefficient is based

on the flow area of the orifice holes and the tie rod computer program loss coefficient is based upon tie rod channel flow area, the above value is corrected to one of 0.85 based upon tie rod channel flow area. This value was then used in the tie rod computer program as an exit loss coefficient.

2.2 Beryllium Reflector Assembly Flow Tests

The beryllium reflector holes use about 20% of the reactor coolant flow, and have the highest unorificed pressure loss in the system. Consequently the pressure drop across the reflector holes sets the pressure drop across the entire reflector system. The flow passage consists essentially of the reflector inlet support ring, reflector cooling holes, and outlet support ring. The support rings are separated from the cooling holes by thin plenum chambers. Since the holes in the support rings and the reflector are not aligned, cross flow occurs in the plenum chambers. The loss coefficients for both the inlet and outlet cannot be predicted analytically with any degree of certainty due to the small size of the plena and the existence of cross velocities in them. The reflector assembly flow tests were initiated to determine these loss coefficients and thereby fix the overall reflector pressure drops.

Preliminary testing on air has been completed⁽²⁾. However, due to the fact that the air supply pressure was not high enough to alleviate compressibility effects and the lack of experimental verification of similitude between air and hydrogen, tests will be continued on hydrogen to determine the loss coefficient under actual full power operating conditions.

The results of the preliminary air tests are shown in Figures 8 - 12.

Figure 8 shows that the loss coefficient for the holes in the inlet support ring (based upon hole diameter) is independent of the plenum height, and appears to be flattening out at the higher Reynolds Numbers. Thus, if we were to extrapolate the loss coefficient up to the design Reynolds Number of 8×10^5 a value for the loss coefficient of 1.26 would result. Figures 9 and 10 show the loss coefficient for the inlet to the reflector cooling holes. Figure 9 shows the marked effects of inlet radius. As the radius increased (i.e., the flow transition becomes more gradual) the loss coefficient decreases. Figure 10 shows that the inlet plenum height has little or no effect on the loss coefficient. The loss coefficient for the inlet to the cooling holes is taken to be 1.55 (based upon tube diameter). These two loss coefficients can be combined into a single inlet loss coefficient for use in the MCAP reflector flow balance. For use in this program the loss coefficient is based upon the beryllium reflector cooling hole diameters. This correction calculation results in an inlet loss coefficient of 3.71 and has been incorporated in the reflector flow balance to determine the flows and temperatures in the reflector.

At the exit of the cooling holes, the loss coefficient (negative values denotes pressure recovery) was found to be practically constant (at -0.26 based on hole diameter) independent of Reynolds Number. This is shown plotted in Figure 11. Unfortunately, the supply pressure was not high enough (maximum of 120 psig) to prevent compressibility effects from showing up in the loss coefficient for the exit support ring. This data is plotted on Figure 12. An estimate 1.6 has been made for the support ring loss coefficient based upon this data. This assumes that the loss coefficient curve has flattened

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out prior to the onset of compressibility effects. These two loss coefficients can be combined into an equivalent exit loss coefficient based upon the coolant hole diameters. This value was calculated to be 0.785 and has been incorporated into the reflector flow balance.

2.3 Fuel Element Orifice Flow Tests

Preliminary measurement of orifice coefficients for production type fuel element orifices has been performed on two 50 mil orifices (diameters 0.05090 and 0.05060") and four 60 mil orifices (diameters 0.06029, 0.06080, 0.06077, and 0.06073 inches). The results of these tests have been reported⁽³⁾ and are being incorporated into the orifice selection computer program.

The design significance of the data is that it will provide a background of data upon which to select a design loss coefficient for a particular size orifice. Selection or rejection of a particular orifice will depend upon whether it is within the allowable limits of this design loss coefficient.

2.4 Support Block Flow Tests

Preliminary data⁽⁴⁾ has been obtained on the temperature behavior of the tie rod button. This data seems to indicate that cone tip temperature rises as the position of the cone is changed from deep recession (in the support block), reaching a maximum at a rather shallow recession. As the cone is moved further outward, the cone tip temperature decreases. It has been tentatively concluded that the latter phenomenon is due to the emerging tip acting as a center body of a diffuser thus permitting smoother flow with less mixing. This data was obtained at low Reynolds Numbers (in the range

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of 500 - 1500) and must be extended into the turbulent regime closer to the design value of 10,000 before any final conclusions can be formulated as to whether a cone tip temperature problem exists and whether movement of the cone tip either inward or outward would alleviate this problem.

The design significance of these test results is that they will permit the evaluation of cone tip temperatures under these complex flow conditions.

2.5 Single Element Corrosion and Flow Tests

Initial data has been obtained but sufficient information is not yet available upon which to evaluate the design significance.

3.0 CONCLUSIONS

Concrete design significance can only be attached to the results of two tests since these tests are the only ones complete to a sufficient extent to provide data for design evaluation. These tests are the tie rod flow test (hanger, centering bushing, and core) and the beryllium reflector assembly flow test on air.

The results of these component tests have been used to size flow control orifices and determine pressure loss coefficients. The latter, in turn, determine the flow distribution within portions of the reactor.

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TIE ROD HANGER FLOW SCHEMATIC

PLENUM
FIGURE 1

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TIE ROD HOLDER LOSS COEFFICIENT
AS A FUNCTION OF HOLDER SLOT AREA

REFERENCE: WANL-TME-402

FIGURE 3

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FIGURE 4

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FIGURE 5

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FIGURE 7

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FIGURE 8

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LOSS COEFFICIENT FOR INLET TO THE REFLECTOR VS.
 REYNOLDS NUMBER
 (BASED ON TUBE DIAMETER)
 FOR VARIOUS INLET GEOMETRIES

INLET PL.	SHIM ROD	# SIZE HOLES	OUTLET PL.	# SIZE HOLES	RAD.	PSI
—— 1/8 IN.	NO	15 x .125	1/16	41 x .081	NO	120
--- 1/8 IN.	NO	15 x .125	1/16	41 x .081	1/8	120
----- 1/8 IN.	NO	15 x .125	1/16	41 x .081	1/4	120

REFERENCE: WANL-TME-333

REYNOLDS NUMBER
 FIGURE 9

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FIGURE 12

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