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**Hydraulic Testing of Modified Neutron
Source Rod in Type Q Septifoil (U)**

by

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Table of Contents

Introduction	1
Summary	2
Apparatus	2
Non-Prototypicalities	3
Instrumentation and Data Acquisition	5
Experimental Procedure	6
QA Considerations	6
Test Matrix and Results for Original Source Rod	6
Test Matrix and Results for Modified Source Rod	7
Conclusions	8
References	9
Tables	10
Figures	14
Appendix	27

Hydraulic Testing of Modified Neutron Source Rod in Type Q Septifoil (U)

Introduction

On Monday, May 25, 1992 a leak was detected as the K Reactor was proceeding to initial criticality. The partial length control rods were being withdrawn when leak detectors alarmed due to coolant leaking onto the top of the reactor tank. The apparent source of this water was the septifoils. The reactor was shut down quickly.

The septifoils used in K Reactor are of a new design, Type Q. The primary reason for the change was to assure cooling of the control rods in the septifoils in the event of a LOCA. The Type Q septifoil had been tested in the Long Term Flow Facility of the Heat Transfer Laboratory (HTL) under Task 90-074-1 (see References).

Actions were started immediately to determine the reason for the leak. Initial activities in NRTSC focused on conducting scoping experiments in the HTL to identify potential causes of the leak. These activities were covered under Task 92-056-0. On May 27, 1992 the probable source for the leak was identified during the scoping task testing activities. The source of the leak was from a flow path through the hollow extension tube which connects to the top of the partial length control rods. This extension tube has holes in its bottom and top. As the partial length rods were raised the extension tube provided a low resistance coolant flow path which allowed water to flow from the top of the septifoil stand pipe.

The scoping task was followed by critical task 92-057-1, in which four possible solutions to the problem of overflow were investigated [Steimke, Fowley and Guerrero, 1992]. The adopted long term solution was to modify the partial length control rods to make them nearly identical hydraulically to the full length control rods [Morrison, 1992].

Two of the sixty one septifoils contain a neutron source rod containing a californium capsule in the central position of the septifoil, replacing a cadmium full length control rod. The source rods have two functions, to initiate the nuclear reaction more smoothly and to provide a baseline neutron flux for the instruments. The normal procedure has been to start the nuclear reaction with the source rods fully inserted, which places the californium capsule at mid height of the reactor. After the nuclear reaction has been started, the source rod is lifted enough to place the capsule above the core. The source rods have two long hollow regions which create leak paths similar to that in the former partial length control rods. Therefore, it was expected that the two septifoils containing source rods would overflow if full septifoil flow was used as the source rods were being lifted. As part of the testing for Task 92-057-1 a procedural change was tested which had the intent of preventing overflow from the two septifoils which contain source rods; the source rods were kept fully seated instead of being lifted. Freeboard, the distance from the water level in a guide tube to the top of the guide tube assembly, provides a measure of the margin of safety. For tests performed for the conditions of normal operation this procedural change resulted in freeboards greater than 24 inches, which was satisfactory. However, freeboards were much less, and therefore unsatisfactory, during scram conditions. Therefore, the decision was made to redesign the source rods to eliminate the internal flow paths. The present task, 92-091-1, was initiated to redesign and test the source rods under normal and scram conditions.

Summary

A Type Q septifoil, two modified partial length control rods, four full length control rods, a source rod containing a dummy neutron source and a guide tube assembly were installed in the Long Term Flow Facility (LTFF) of the HTL. The water level inside the guide tubes over the septifoil was measured by the use of sight tubes connected to pressure taps on the guide tubes or by pressure gages. Pressures were measured at tank bottom and inside the septifoil. The target tank bottom pressure for the experiments was 12.76 psig which gives the same no-flow freeboard in the LTFF as a blanket gas pressure of 5.00 psig in K Reactor. The first series of tests was performed with the existing source rods under a previous Task Plan, 92-057-1. The source rod was kept fully seated during testing to reduce the effect of the flow path through the source rod. Freeboards were adequate during the conditions of normal operation, but inadequate during scram conditions. The minimum freeboard measured during a scram for a septifoil flow of 106 gpm was 20 inches and 7 inches for 120 gpm, adjusted to the target tank bottom pressure. During a control rod scram the full length control rods are driven into the reactor core as a gang. The reason that freeboards are small during a scram is that the rods pass through positions that tend to reduce freeboard, rather than the velocity of the rods having a negative effect. In fact, a lower freeboard occurs if the rod are held motionless at certain positions.

The second series of tests was performed with a modified source rod in which the flow path through the source rod was eliminated. For these tests the source rod was lifted after the control rods had been positioned, the usual procedure in SRS Reactors. The source rod design change increased freeboards such that they were adequate under all conditions. The minimum freeboard measured during normal operating conditions was 45 inches for 106 gpm and 37 inches for 120 gpm, both adjusted to the target freeboard. The freeboard measured during a scram at 106 gpm and adjusted to the target tank bottom pressure was 39 inches. Freeboards were measured separately for the six outer tubes of the guide tube assembly. Freeboards were nearly the same, differing only two inches between tubes.

Shadday [1992] analyzed the hydraulics of the modified source rod in the Type Q septifoil and concluded that the flow path through the modified source rod could not pressurize the guide tubes, the effect that caused the overflow in K Reactor on May 25. He also concluded that the freeboards computed in the analysis of the modified partial control rods [Shadday, et al., 1992] bounded the freeboards for the septifoils containing source rods.

Apparatus

A Type Q septifoil containing one neutron source rod and six control rods was tested hydraulically in the HTL. Figure 1 shows a side view of the Type Q septifoil in K Reactor. Coolant enters from the bottom, flows past the control rods and the source rod and out the slots and holes near the Poison Plate. The elevations of the control rods are used to control reactor power and axial flux shape. Two of the sixty one septifoils in K Reactor contain two partial length lithium control rods, three full length lithium control rods, one full length cadmium control rod and one source rod. The control rods are illustrated in Figures 2 and 3. The full length lithium control rods have lithium-aluminum alloy, the active material, extending the full length of the core. Above the active region is a hollow extension tube with holes at either end. The holes allow some circulation of coolant and also allow coolant to drain when the rod is removed from the reactor. The existing, and soon to be replaced, partial length rods have a shorter active region and a long hollow region above the active region in the extension tube. The existing partial length rods are described because their hydraulic similarity to the existing source rods triggered concern about the source rods. The modified partial length rods have the same size active region as the present partial rods, but have solid aluminum above the active material. The hollow extension tubes for the full length lithium control rods and the modified partial length control rods are the same length and are nearly identical. The only difference is two extra holes drilled through the modified extension to facilitate identification. Above each cadmium

rod is a solid extension tube. All of the extension tubes have a knob at the top which can be gripped to lift the rod. The present arrangement of the control rods in the septifoil is shown in Figure 4. The control rods are designated by both number and letter. The perforated web inside the septifoil is not shown. Note that the partial rods are opposite each other and that central position is occupied by the source rod or a cadmium full length control rod.

The existing source rod is shown in Figure 5. It is largely hollow and has perforations. The two hollow sections can pass a significant coolant flow. The source capsule is located near the mid plane of the core when the source rod is fully down. The modified source rod is also shown in Figure 5. The large hollow regions have been replaced with solid aluminum, eliminating the major internal flow paths. There is a fourteen inch long hollow region in the vicinity of the source rod with holes at the top and bottom. The internal structure is restrictive and should pass only a small flow.

Tests were conducted at the LTFF of the HTL. The LTFF has a tank and a hydraulic loop. It does not have a hydraulic plenum, shield or Poison Plate but its total height is the same as K Reactor. The distance from tank bottom to tank top is 239.5 inches. The LTFF is shown in Figure 6. A reactor grade septifoil was placed in the central position of the tank. A pressure tap was added 0.85 inch above the top of the oval slots where the coolant discharges. Since the LTFF does not contain a top shield or a Poison Plate and these structures are located close to the discharge holes of the septifoil, a simulated top shield and a simulated Poison Plate were added. The simulated plates were one inch thick Lexan ® disks separated by 0.75 inches. The bottom of the top plate was flush with the bottom of the semi-permanent sleeve. Both plates have an outside diameter of 7.63 inches. The inside diameters of the shield simulator and the Poison Plate simulator are 4.25 and 4.75 inches, respectively.

A reactor grade guide tube assembly was placed over the septifoil as shown on Figure 1. The guide tube assembly consists of seven tubes clustered in a hex. Pressure taps were attached to the outside tubes 102.9 inches below the top of the guide tube assembly. Note that there was no pressure tap on center tube because no technique was found to accomplish this without blocking one of the other six tubes. A scoping run was performed at the nominal flow of 106 gpm in which the equivalent blanket gas pressure was raised to the point of spill over to determine when the central tube of the guide tube assembly would leak in relation to the other tubes. The test showed that the water level in the central tube was within one inch of the water level in the other tubes.

Non-Prototypicalities

The following are the non-prototypicalities of the test and the justifications for why they do not affect applicability of the data to the reactor.

1. The tests were run with ordinary water rather than with heavy water.

Justification: Code Development Group members have analyzed the differences in freeboard between heavy and light water for the experiment [Shadday, et al., 1992]. They used the fact that the tank pressure in the experiments was adjusted so that the no-flow freeboard in the experiments was the same as the no-flow freeboard in the reactor with 5 psig blanket gas pressure. They concluded that liquid density has no effect. Liquid viscosity was also shown to have a negligible effect.

2. The experiment simulated the pressure in the tank by the use of a water column above the tank rather than blanket gas.

Justification: The method of creating the pressure boundary condition makes no difference

to the results of the experiment.

3. The experiment simulated the Poison Plate and the shield in the reactor with plastic disks.

Justification: The only effect of those two plates on septifoil flow is that they could increase the hydraulic resistance just outside the exit holes of the septifoil. The disks correctly simulated that resistance. It should be noted that the addition of the two plates in scoping tests had a negligible effect on freeboard.

4. The pin that provided flow to the septifoil in the experiment has less hydraulic resistance than the pins at K Reactor.

Justification: The experiments were controlled on the basis of flow to the septifoil rather than pressure at the inlet pin. Therefore, the difference in resistance did not effect the experimental results.

5. The seven control rods in the guide tube assembly hang from latches. The two latches for the partial length control rods were prototypical. However, the other five latches were not.

Justification: The problem being addressed was caused by flow through the hollow extensions over the partial control rods. The flow was driven by the lower hole in the partial rods being exposed to a pressure gradient larger than the hydrostatic pressure gradient. The holes in the extension over the full length rods are exposed only to the hydrostatic pressure gradient. Therefore, there will be no flow out of the upper hole of the full length control rod extension. A non-prototypical latch would make a difference only if there was flow in that region.

6. The upflow pin in the bottom of the reactor tank fits inside a hole in the bottom of the septifoil. There is a slip fit but no seal. The design specifications of the two components imply a diametral clearance of from 6 mils to 11 mils. The diametral clearance for the experiment is 5 mils.

Justification: The only significance of the clearance is that water can leak through the gap when there is a pressure difference between the inside and outside of the septifoil. Calculations for the leak flow indicate that it will be negligible for all clearances up to 11 mils for the pressure differences expected under normal operation.

7. The source rod that was tested was a preliminary design, not the final design. The external structures of the two designs were the same, but the internal structures differed.

Justification: Both the preliminary and final source rod designs have a 14 inch long hollow section that can pass a small coolant flow. Shadday [1992] expressed the opinion that this small flow has a negligible effect on the freeboard for the septifoil. The hollow section in the final design is more restrictive to flow than the preliminary design. Therefore, if there is an effect of the hollow space it will be larger for the preliminary design, which was the design that was tested. Therefore, the test data are conservative with respect to the final design.

Instrumentation and Data Acquisition

Flow to the septifoil was measured using a orifice plate meter (TR-20267) connected to a differential pressure gage (TR-20267-1). The pressure gage has a current output which was converted to a voltage using a calibrated resistor. Prior to September 9 the resistor was TR-1387. After that date a new data acquisition system was used and it was convenient to use another

resistor, TR-469A. Unfortunately resistor TR-469A was accidentally destroyed close to the end of testing on October 9, which prevented a post-test calibration for it. It was then necessary to rule out the possibility that the resistance of the resistor had changed during the course of testing, which would have changed the indicated flow. This was done by replacing the damaged resistor with the original resistor, TR-1387. The last test prior to TR-469A being destroyed was repeated. The measured freeboards were the same to within the measurement uncertainty. This would have not been the case if the resistance had changed. Therefore, the resistance did not change. The overall uncertainty on flow is ± 2 gpm. All uncertainties stated in this report are based on 95% confidence level.

Tank bottom pressure was measured using Heise pressure gage TR-428 at the same elevation as the tank bottom. The uncertainty is ± 0.05 psi. A pressure tap was installed in the side of the septifoil just above the outlet slots, 184.9 inches above tank bottom. The pressure at that tap was measured with a Heise pressure gage at the same location, TR-426. Its accuracy is ± 0.08 psi. The gage stopped functioning on September 29. Therefore, no data are available for that gage after that date. Because it can not be post test calibrated, the data for the tap must be considered scoping. However, those data are not critical and were not used to support the decision to adopt the new source rod design. The pressures at the gages were referenced to the elevation of the tap. The supply pressure to the septifoil pin was measured using a Heise pressure gage (TR-432) located 11.5 inches below tank bottom. The location of the pressure tap is shown on Figure 6. The uncertainty is ± 0.25 psi. Barometric pressure was measured with TR-710. The uncertainty is ± 0.09 inch Hg. The temperature of the water in the tank was measured with a Type J thermocouple. The uncertainty is $\pm 2.2^\circ\text{C}$.

Freeboards for four of the guide tubes were measured using transparent 1/2" outside diameter Tygon ® tubes were connected to the pressure taps on the guide tube assembly. The sight tubes lead upward and were strapped to the guide tube assembly to allow visual measurement of the water level in each guide tube. Freeboard was measured with a ruler and manually recorded in the laboratory notebook (WSRC-NB-92-273). Freeboard is the distance from the top of the guide tube assembly to the water level in a sight tube. Freeboards were usually reported to the nearest inch. The gage pressures and thus freeboards inside guide tubes A and C were measured using Heise pressure gages, TR-434 and TR-300. The use of two methods for measuring freeboard allowed for periodic comparisons. Only the pressure gages could be used to measure transient freeboards.

The flow, temperature and pressures were recorded with a Macintosh computer based data acquisition system using Workbench® software. M. D. Fowley prepared a Workbench worksheet which tells the computer which data channels to sample, the sampling rate, how large the signal will be and the equations for converting the voltage signals to engineering units. Workbench stores the voltage and engineering unit data for each run in tabular form using a file name supplied by Fowley, who also recorded the conditions of the test and the file name in the logbook. Data were reduced using Trapeze® software. Data files generated by Workbench were imported into the Trapeze spreadsheet prepared by J. L. Steimke which computed time averages of the measured variables and made plots of some of the variables versus time. The computed averages for each run were electronically copied into the data tables in this report.

Experimental Procedure

This is a summary of the written procedure for this test [Hovis, 1992]. At the beginning and end of every day of testing the instruments were logged with no flow to record a known baseline. For the tests with stationary rods, the rods were positioned and the correct flow established. The instruments were watched until steady state was achieved. Then data were logged and the freeboards in the guide tubes were observed and recorded. For the tests with moving rods, the

rods were placed in the correct starting position and the requested flow was established. The data log was started, the rods were moved with the requested order and speed, then the log was stopped.

QA Considerations

All requirements for critical data in 1Q34 were met. The experiments were performed following an approved Critical Task Plan [Steimke, 1992] and Technical Procedure [Hovis, 1992]. All of the instruments had current calibrations before the start of testing and were given post-test calibrations. This report was technically reviewed.

QAP IV-1 of 1Q34 requires that data acquisition software be verified by the user. Workbench and Trapeze were simultaneously verified by means of a loop calibration. There are three types of instrumentation; pressure gages, a thermometer and a flow meter. The loop calibration for the pressure gages consisted of pressurizing the flow loop under a no flow condition with two different heads of liquid measured with a ruler. The Workbench worksheet was used to log the outputs both times. The Trapeze spreadsheet was used to time average the data. The output pressures agreed with the known hydrostatic heads. The thermocouple in the flow loop was checked by removing it from the loop while keeping it connected to the DAS. It was placed in stirred beakers of water at two different temperatures with a calibrated glass thermometer. The output of the Trapeze spreadsheet agreed with the thermometer reading. A loop calibration of the flow meter was performed at the same time as the post-test calibration for the flow meter. The voltage output of the flowmeter was connected to both a voltmeter and the DAS. For every flow of the calibration data were logged on the DAS. The Trapeze spreadsheet was used to time average the results. The Trapeze flows agreed with the calibration flows. Details of the loop calibration are reported in Appendix A.

Test Matrix and Results for Original Source Rod

Tests were run in which the original source rod in the septifoil was kept fully down at all times to reduce the effect of the flow through the hollow portion of the source rod. The test matrix and results for these tests are shown in Table 1. Some runs are duplicated. The day and time are listed to allow access to the data files on the DAS computer. The tank pressure measurement is located at tank bottom. The supply pressure, P_{pin} , is located 11.5" below tank bottom. The septifoil pressure is located just above the oval exit holes. The freeboards for the six guide tubes are with respect to the top of the guide tubes. The temperature listed is for the water. The reactor blanket gas pressure forces moderator up the guide tubes to an elevation of 10' 3" under no flow conditions. The top of the guide tube assembly is at an elevation of 16' 4". Therefore, the freeboard for a nominal 5 psig blanket gas pressure for no flow is 73" for the reactor. That is the target freeboard for the laboratory tests. The rod elevations are the heights of the rod bottoms with respect to the orifice plate near the bottom of the septifoil. Tests were run at the nominal septifoil flow of 106 gpm and the upper limit flow of 120 gpm. Tests 501 through 509 represent rod positions that would be observed during startup and normal operation. The tank bottom pressures are somewhat lower than the target value of 12.76 psig. After adjusting the freeboards to the basis of the target tank bottom pressure, the minimum freeboard for startup and normal operation is 36 inches for 106 gpm and 27 inches for 120 gpm. Tests 510 and 511 freeze the rods at two positions that they would pass through during a scram. After adjusting the freeboards to the basis of the target tank bottom pressure, the minimum freeboards for the frozen scram positions are 15 inches for 106 gpm and 1 inch for 120 gpm for the original source rod held fully down.

Transient tests were run with the expectation that a damping effect would make the minimum freeboard during a scram greater than for the frozen rod position. There is a two or three inch zone of rod elevations with particularly low freeboards. During actual scram movements the

rods move through that zone in a second or two, not enough time for the freeboard to respond fully. The transient test was run by positioning the rods as follows. Partial rods A and D were held at an elevation of 53 inches. The source rod was kept fully down. Full rods B, C, E and F were ganged together. The gang was lowered at 1.6 inches per second. The results for flows of 106 gpm and 120 gpm are shown in Figures 7 through 10. Figures 7 and 9 show the freeboards for tubes A and C of the guide tube assembly. Figures 8 and 10 show the pressure at the pin supplying flow to the septifoil. This pressure is shown because no sensor was attached to the rods to record their instantaneous position. As the rods are scrambled the flow resistance of the septifoil increases and the pin pressure increases. Therefore changes in pin pressure indicate rod motion. Vertical lines on the figures show the start and stop of the rod movement. The figures show that the minimum freeboards are 20 inches and 7 inches for flows of 106 gpm and 120 gpm for the original source rod held fully down. Measured minimum freeboards increased by about five inches as the result of damping. However, the freeboards are less than the guideline of 24 inches. This result prompted testing of a modified source rod in the septifoil.

Test Matrix and Results for Modified Source Rod

Because freeboards under scram conditions were marginal for the transient tests in which the source rod was kept fully down, the decision was made to redesign the source rod to eliminate the flow path through the hollow part of the rod. This would make the source rod nearly identical to the full length control rod and the modified partial length control rod. It was anticipated that this would allow the source rod to be pulled out of the core after startup, the usual procedure. The test matrix for the steady state tests to address this modification is shown in Table 2. The partial rods were moved to the typical elevation of 36 inches with the source rod and the four full rods fully down. Then tests were performed with the full rods and the source rod successively pulled to various elevations. Each test run with a different control rod position was conducted at the nominal flow of 106 gpm and repeated at 120 gpm to simulate the maximum flow variation. The target equivalent blanket gas pressure was 5 psig which corresponds to a tank bottom pressure in the LTFF of 12.76 psig. Tests 1 through 8 in Table 2 were run for rod positions that could be seen during startup and normal operation. Test 9 in Table 2 is a frozen scram rod position. The results are listed in Table 2 and a summary plot of the minimum freeboards for tests 2 through 8 is given in Figure 11. Zero Veeder Units means that all five full rods are fully out and 5000 VU means all five full rods are fully in. The minimum freeboard for 106 gpm, adjusted to the target tank bottom pressure, was 41 inches for run 9A. This freeboard decreased to 32 inches when the flow was increased to 120 gpm.

The freeboard in the central guide tube was not instrumented. Therefore, there was concern that the freeboard might be different than for the other tubes. A scoping test was run in which the equivalent blanket gas pressure was increased until the freeboards were high enough so they could be observed visually from the top of the guide tube assembly. At 106 gpm the freeboard in the source rod position differed from the average of the others by no more than an inch.

Transient tests were run with modified partial control rods using the rod movements listed in Table 3. A limitation of the experiment should be noted. The hoist used to lift and lower the control rods had 130 inches of travel, so that the rods could not be moved the full 177 inches in one smooth motion. The rods were moved part of the distance, then the hoist was repositioned on the rods and the movement was completed. Freeboards, pin pressures and flow were logged once per second. Plots of freeboards and pin pressure are shown in Figures 12 through 19. Because the raw data were noisy (standard deviation of noise was one inch of freeboard), a running average over five seconds was computed and plotted. The plots show periods when the rods are stationary as well as periods when the rods are moving. Vertical lines indicate the boundaries between data sets. Sometimes hours passed in that interval. Freeboards are plotted for tubes A and C of the guide tube assembly that were instrumented with pressure gages. Tube

A contains a partial rod and tube C contains a full length rod. Sight tubes were attached to the other tubes. Visual observations were made of the sight tubes. The visual observations in the sight tubes were nearly the same as the measurements made with the pressure gages. As with the earlier transient test the pin pressure was used to determine when the rods started their motion and when they stopped.

The data logs at 1036 and 1111 on September 29 were run by mistake. The conditions for those runs, four rods suspended motionless at 174 or 176 inches, could not be realized in the reactor. The only time that four rods would be aligned at that elevation would be a scram when they would be moving. Transient freeboards, converted to the target tank bottom pressure, for all of the transient tests with the modified source rods, including the two unintended runs, are plotted in Figures 12 through 19. Data log 1620 on October 6 shows the intended scram situation. Excluding the two unintended logs, measured freeboards during the transients covered a range of 39 to 55 inches of freeboard for a flow of 106 gpm. Transient tests were not run for a septifoil flow of 120 gpm. However, for the steady state tests the largest difference in freeboards observed for flows of 106 and 120 gpm was 9 inches. Subtracting 9 inches from 39 inches gives 30 inches, which is greater than the guideline freeboard of 24 inches. Freeboards listed are arithmetic averages for a run including those runs which are transients. There were some dynamic effects. The data logs at 1036 and 1111 on September 29 showed low freeboards because the rod gang was held motionless inside a zone two or three inches wide that minimized freeboard. During a scram the rod gang drives through that zone in a second or two and there is insufficient time for the level of the free surface in the guide tube assemble to adjust upward.

Conclusions

Two solutions to the problem of overflow for the two Type Q septifoils that contain source rods were tested. The method of keeping the source rod fully down at all times when flow is being supplied to the septifoils gave a marginal result under the transient conditions of a scram. The method of redesigning the source rod to resemble a full length control rod hydraulically gave acceptable freeboards under all conditions and is the recommended solution to the problem.

References

- Banks, J. J., 1992, "Design Input for PMT-92-0797"
- Flach, G. P., 1992, "Source Rod Test Matrix Request", NES-CDG-920143, August 6.
- Fowley, M. D., 1991, "Type Q Septifoil Hydraulic Test", WSRC-TR-91-125.
- Fowley, M. D., 1992, laboratory notebook, WSRC-NB-91-158, pp. 197-205.
- Guerrero, H. N., 1992, "Additional Septifoil Tests," NES-ETH-920261, July 30.
- Hovis, G. L., 1992, "Septifoil Leakage Tests", TP-92-024, May 29.
- Punch, T. M., 1992, "Septifoil Guide Tube Overflow During K14.1 Startup", WSRC-TR-92-42-064.
- Morrison, J. M., 1992, "Authorization to Proceed With Partial Rod Fabrication", RRD-RRP-920234.
- Shadday, M. A., 1991, "Hydraulic Characteristics of the Type Q Septifoil", WSRC-TR-91-612.
- Shadday, M. A., 1992, "Influence of Modified Source Rods on Septifoil Guide Tube Freeboard", NES-CDG-920189, October 9.
- Shadday, M. A., N. M. Askew, G. P. Flach and L. D. Koffman, 1992, "Type Q Septifoil Guide Tube Freeboard; Model Description and Results (U)", WSRC-TR-92-357.
- Steimke, J. L., 1991, "Design and Testing of Septifoil Modification", Rev. 2, Task Plan 90-074-1, May.
- Steimke, J. L., Hovis, G. L., Hart, C. M., Fowley, M. D., Whitehouse, J. C., 1992 "Measurements of Septifoil Freeboard", NES-ETH-92014, June 3.
- Steimke, J. L., 1992, "Septifoil Leakage Test Matrix," NES-ETH-920255", July 28.
- Steimke, J. L., Fowley, M. D. and Guerrero, H. N., 1992, "Hydraulic Testing of Type Q Septifoils Including Modifications", WSRC-TR-92-370, September.
- Whitehouse, J. C., 1992, "Test Matrix for Control Rod Startup and Scram Tests", NES-ETH-920201, June 4.
- Zagrodnik, A. A., 1992, "Septifoil Leakage Verification and Resolution", Technical and QA Plan, Task 92-057-1, Rev. 3.

Table 1
Test Matrix and Data For Original Source Rod
and Modified Partial Length Rods in Septifoil

run	flow gpm	rod elevations, inches						day	time	point no.	flow (gpm)	Plank (psig)	Ppin (psig)	Psept (psig)	Temp. °C	Freeboard, inches					
		A	D	G	E	B	C									A	B	C	D	E	F
.	0	0	0	0	0	0	0	8/11/92	09:06:00	906	-7.5	12.67	13.06	6.05	28.6	43	43	43	43	43	43
501A	106	0	0	0	0	0	0	8/11/92	09:49:00	951	106.3	12.65	49.09	6.94	34.0	43	43	43	43	43	43
501A	106	0	0	0	0	0	0	8/11/92	10:00:00	1002	106.1	12.64	49.05	6.94	34.2	43	43	43	43	43	43
501B	120	0	0	0	0	0	0	8/11/92	10:07:00	1009	119.4	12.64	58.77	7.17	34.2	35	35	35	35	35	35
502A	106	36	0	0	0	0	0	8/11/92	10:32:05	1034	106.1	12.64	47.14	6.96	34.0	40	40	40	40	40	40
502B	120	36	0	0	0	0	0	8/11/92	10:23:14	1025	119.5	12.64	56.78	7.21	34.1	31	31	31	31	31	31
503A	106	36	0	124	0	0	0	8/11/92	10:57:00	1059	106.2	12.64	43.52	6.95	33.6	41	41	41	41	41	41
503B	120	36	0	124	0	0	0	8/11/92	11:07:53	1108	119.3	12.64	52.28	7.23	33.4	32	31	31	32	31	31
504A	106	36	0	177	0	0	0	8/11/92	12:31:00	1233	105.9	12.65	41.29	6.78	36.2	45	45	45	45	45	45
504B	120	36	0	177	0	0	0	8/11/92	11:22:00	1124	119.5	12.64	49.97	7.07	33.2	37	38	38	37	38	38
504B	120	36	0	177	0	0	0	8/11/92	12:15:19	1216	119.5	12.64	50.00	6.98	32.2	37	38	38	37	38	38
505A	106	36	0	177	124	0	0	8/11/92	12:47:04	1249	105.9	12.65	39.59	6.80	35.9	42	42	42	42	42	42
505B	120	36	0	177	124	0	0	8/11/92	12:56:26	1258	119.8	12.65	48.10	7.00	35.8	33	33	33	33	33	33
506A	106	36	0	177	177	0	0	8/11/92	13:21:03	1323	106.2	12.64	38.76	6.68	35.5	47	47	47	47	47	47
506B	120	36	0	177	177	0	0	8/11/92	13:12:00	1314	119.9	12.65	47.12	6.84	35.6	40	40	40	40	40	40
507A	106	36	0	177	177	124	0	8/11/92	13:35:23	1334	106.2	12.65	37.87	6.70	35.3	44	44	44	44	44	44
507B	120	36	0	177	177	124	0	8/11/92	13:49:00	1351	119.6	12.65	45.80	6.86	35.1	36	36	36	36	36	36
508A	106	36	0	177	177	177	0	8/11/92	14:13:00	1415	105.9	12.64	37.36	6.75	34.9	45	45	45	45	45	45
508B	120	36	0	177	177	177	0	8/11/92	14:03:23	1405	119.7	12.64	45.50	6.93	35.0	37	37	37	37	37	37
509A	106	36	0	177	177	177	124	8/11/92	14:25:00	1427	105.9	12.64	36.93	6.78	34.7	40	40	40	40	40	40
509B	120	36	0	177	177	177	124	8/11/92	15:00:00	1502	119.6	12.64	44.27	6.98	34.5	32	31	31	32	31	31
510A	106	36	0	124	124	124	106	8/11/92	15:31:23	1533	106.4	12.64	40.78	7.00	34.2	25	22	22	25	22	22
510B	120	36	0	124	124	124	106	8/11/92	15:21:28	1523	119.3	12.64	48.28	7.23	34.3	13	10	10	13	10	10
511A	106	72	0	124	124	124	106	8/11/92	15:50:13	1552	106.2	12.64	40.90	7.09	34.0	19	19	19	19	19	19
511B	120	72	0	124	124	124	106	8/11/92	16:00:05	1602	119.7	12.64	48.42	7.36	34.0	5	5	5	5	5	5
.	0	0	0	0	0	0	0	8/11/92	16:10:05	1610	-5.5	12.66	13.07	6.09	33.6						

Table 2.
Test Matrix and Data for Modified Source Rod
and Modified Partial Length Rods in Septifoil

run	flow gpm	Rod Elevations, inches						day	time	point no.	flow (gpm)	Plank (psig)	Ppin (psig)	Psept (psig)	Temp. °C	Freeboard, inches					
		AD	G	E	B	C	F									A	B	C	D	E	F
.	0	0	0	0	0	0	0	9/23/92	09:14:05	914	7.7	12.84	13.28	6.24	35.3	69.5		69.7			
1A	106	0	0	0	0	0	0	9/23/92	09:46:27	948	105.6	12.90	51.93	7.36	38.0	43.8	44	43.8	44	44	44
1B	120	0	0	0	0	0	0	9/23/92	09:56:59	959	120.8	12.90	63.14	7.69	38.3	37.7	39	37.7	39	39	39
2B	120	36	0	0	0	0	0	9/23/92	10:15:00	1017	121.0	12.90	60.79	7.52	38.5	35	37	36.5	35	37	37
2A	106	36	0	0	0	0	0	9/23/92	10:25:00	1027	106.5	12.91	50.67	7.22	38.6	42.6	44	43.7	43	44	44
3A	106	36	0	177	0	0	0	9/23/92	12:54:19	1257	106.1	12.91	42.38	6.93	38.8	48.9	51	50.4	49	51	51
3B	120	36	0	177	0	0	0	9/23/92	13:05:00	1307	119.8	12.91	51.34	7.13	38.8	42.8	45	44.6	43	45	45
4B	120	36	0	177	124	0	0	9/23/92	13:29:00	1331	119.9	12.91	49.12	7.16	38.7	40.1	42	41.7	41	42	42
4A	106	36	0	177	124	0	0	9/23/92	13:39:10	1341	106.4	12.91	40.03	6.99	38.7	46.6	48	47.9	47	48	48
5A	106	36	103	177	124	0	0	9/23/92	13:59:26	1401	106.4	12.91	39.48	7.04	38.6	46.5	48	47.7	47	48	48
5B	120	36	103	177	124	0	0	9/23/92	14:08:59	1411	120.3	12.91	47.20	7.25	38.6	39.8	42	41.2	41	42	42
6B	120	36	103	177	177	0	0	9/23/92	14:24:08	1426	120.2	12.91	46.11	7.11	38.7	38.1	40	39.2	38	40	40
6A	106	36	103	177	177	0	0	9/23/92	14:33:59	1436	106.4	12.91	38.42	6.95	38.7	45	46	45.9	45	46	46
7A	106	36	103	177	177	177	0	9/23/92	15:11:00	1513	106.4	12.89	37.19	6.94	38.5	42.3	43	42.8	43	43	43
7B	120	36	103	177	177	177	0	9/23/92	15:20:59	1523	120.0	12.88	44.13	7.12	38.6	34.5	35	35.2	35	35	35
8B	120	36	103	177	177	177	177	9/23/92	15:39:59	1542	120.0	12.89	43.02	7.11	38.6	33.2	34	33.3	34	34	34
8A	106	36	103	177	177	177	177	9/23/92	15:51:32	1552	106.4	12.89	36.31	6.90	38.5	41.1	41	41.2	41	41	41
9A	106	36	103	168	168	168	168	9/23/92	16:07:00	1609	106.3	12.89	37.70	7.21	38.4	37.3	37	37.4	37	37	37
9B	120	36	103	168	168	168	168	9/23/92	16:16:59	1619	119.8	12.89	44.38	7.50	38.4	28.3	29	28.4	29	29	29
.	0	0	0	0	0	0	0	9/23/92	16:27:45	1628	4.6	12.80	13.23	6.25	38.3	70.1	70	70.3	70	70	70

• Zero flow point

Septifoil pressures (Psept) are referenced to the elevation of the outlet slots

Septifoil pressures are scoping data because the gage broke and could not be recalibrated.

Table 3
Rod Positions for Transient Experiments with Modified Source Rod

file name	flow gpm	partial rod ht.	G rod ht.	E rod ht.	B rod ht.	C rod ht.	F rod ht.
09/25 1141	0	0"	0"	0"	0"	0"	0"
09/25 1240	106	57"	0"	0"	0"	0"	0"
09/25 1306	106	57"	pull 0" to 128"		0"	0"	0"
09/25 1321	106	57"	128"	128"	0"	0"	0"
09/25 1341	106	57"	177"	177"	0"	0"	0"
09/25 1345	106	57"	177"	177"	pull 0" to 126"	0"	0"
09/25 1400	106	57"	177"	177"	126"	0"	0"
09/25 1415	106	57"	177"	177"	177"	0"	0"
09/25 1456	106	57"	177"	177"	177"	pull 0" to 126"	0"
09/25 1511	106	57"	177"	177"	177"	126"	0"
09/25 1520	106	57"	177"	177"	177"	88"	0"
09/25 1547	106	57"	177"	177"	177"	88"	0"
09/25 1611	0	0"	pull 0" to 103"	177"	177"	0"	0"
09/29 0848	0	0"	0"	0"	0"	0"	0"
09/29 1036	106	57"	174"	174"	174"	174"	174"
09/29 1111	106	57"	scram 176"to 40"		scram 176"to 40"	scram 176"to 40"	scram 176"to 40"
09/29 1125	106	57"	40"	40"	40"	40"	40"
09/29 1146	106	57"	175"	175"	175"	175"	0"
09/29 1149	106	57"	scram 175"to 40"		scram 175"to 40"	scram 175"to 40"	0"
09/29 1159	106	57"	40"	40"	40"	40"	0"
09/29 1256	106	57"	175"	175"	175"	0"	0"
09/29 1523	106	57"	175"	175"	175"	0"	0"
09/29 1540	106	57"	scram 175"to 40"		scram 175"to 40"	0"	0"
09/29 1550	106	57"	40"	40"	40"	0"	0"
09/29 1600	0	0"	0"	0"	0"	0"	0"

Table 3, continued
Rod Positions for Transient Experiments with Modified Source Rod

file name	flow gpm	partial rod ht.	G rod ht.	E rod ht.	B rod ht.	C rod ht.	F rod ht.
09/30 0916	0	0"	0"	0"	0"	0"	0"
09/30 0950	106	57"	103"	0"	0"	0"	0"
09/30 1001	106	57"	103"	55"	55"	55"	55"
09/30 1009	106	57"	103"	scram 55" to 0"	scram 55" to 0"	scram 55" to 0"	scram 55" to 0"
09/30 1019	106	57"	103"	0"	0"	0"	0"
09/30 1029	106	57"	103"	55"	55"	55"	0"
09/30 1031	106	57"	103"	scram 55" to 0"	scram 55" to 0"	scram 55" to 0"	0"
09/30 1041	106	57"	103"	0"	0"	0"	0"
09/30 1050	106	57"	103"	55"	55"	0"	0"
09/30 1053	106	57"	103"	scram 55" to 0"	scram 55" to 0"	0"	0"
09/30 1102	106	57"	103"	0"	0"	0"	0"
09/30 1111	0	0"	0"	0"	0"	0"	0"
10/06 1534	0	0"	0"	0"	0"	0"	0"
10/06 1618	106	57"	103"	177.5"	177.5"	177.5"	177.5"
10/06 1620	106	57"	103"	scram 177.5" to 114"	scram 177.5" to 114"	scram 177.5" to 114"	scram 177.5" to 114"
10/06 1633	106	57"	103"	114"	114"	114"	114"
10/06 1643	0	0"	0"	0"	0"	0"	0"

Figure 1
Side View of Type Q
Septifoil in Reactor

Figure 2
Full and Partial Length Lithium Control Rods

Figure 3
Modified Partial Control Rod and Cadmium Control Rod

Note: NOT TO SCALE.

Figure 4
Positions of Source Rod and Control Rods
in Type Q Septifoil

Figure 5
Source Rods

Figure 7. Schematic of Modified Long Term Flow Facility

Figure 7
Transient Freeboard in Septifoil Containing
Modified Partial Rods and Original Source Rod

Figure 8
Transient Pin Pressure in Septifoil Containing
Modified Partial Rods and Original Source Rod

Figure 9
Transient Freeboard in Septifoil Containing
Modified Partial Rods and Original Source Rod

Figure 10
Transient Pin Pressure in Septifoil Containing
Modified Partial Rods and Original Source Rod

Figure 11
Effect of Full Length Rod Withdrawal on Freeboard, 106 and 120 gpm
For a Type Q Septifoil Containing Modified Partial Length Control Rods
And a Modified Source Rod

Figure 12
Transient Freeboard in Septifoil Containing
Modified Partial Rods and Modified Source Rod

Figure 13
Transient Pin Pressure in Septifoil Containing
Modified Partial Rods and Modified Source Rod

Figure 14

Transient Freeboard in Septifoil Containing
Modified Partial Rods and Modified Source Rod

Figure 15

Transient Pin Pressures in Septifoil Containing
Modified Partial Rods and Modified Source Rod

Figure 16
Transient Freeboard in Septifoil Containing
Modified Partial Rods and Modified Source Rod

Figure 17
Transient Pin Pressures in Septifoil Containing
Modified Partial Rods and Modified Source Rod

Figure 18
 Transient Freeboard in Septifoil Containing
 Modified Partial Rods and Modified Source Rod

Figure 19
 Transient Pin Pressure in Septifoil Containing
 Modified Partial Rods and Modified Source Rod

Appendix A Loop Calibration of DAS and Software

A loop calibration involving three tests was run to simultaneously check the instruments, the DAS, the Workbench worksheet and the Trapeze spreadsheet. For the first test test system overflow was maintained at the normal level, which was measured with a ruler. The overflow pressurizes the flow loop. The flow loop thermometer was placed in a beaker of water at about 30°C along with a calibrated thermometer. All instruments were logged. Then the overflow level was raised to another level which was also measured with a ruler, the temperature of the water was changed and the instruments were again logged. Finally, the flow meter was removed from the flow loop and calibrated. However, the flow meter was kept connected the DAS as well as the voltmeter used in the calibration. The resulting Workbench data files were imported to the Trapeze program. The outputs of the Trapeze spreadsheet are attached and are compared below with independently determined values. Also attached is a figure showing the important dimensions. Additional details are recorded in the log book, WSRC-TR-92-273.

Comparison of freeboards measured by ruler and DAS

The Trapeze spreadsheet adjusts the measured freeboard by the amount that the tank bottom pressure is off the target value. Given the dimensions of the LTFF and the guide tube, the computed target freeboard is 73 inches for the simulated blanket gas pressure of 5.0 psig. When there is no flow the freeboard reported by the Trapeze spreadsheet should always be 73 inches.

Test 1	72.8"	72.9"
Test 2	72.8"	72.9"

Comparison of pressures measured by ruler and DAS

	<u>By ruler</u>	<u>By Trapeze</u>
TR-428		
Test 1	$357''/12 \quad 62.1/144 = 12.83 \text{ psi}$	12.85 psi
Test 2	$380.3''/12 \quad 62.1/144 = 13.67 \text{ psi}$	13.69 psi
TR-432		
Test 1	$(357''+10.8'')/12 \quad 62.1/144 = 13.22 \text{ psi}$	13.29 psi
Test 2	$(380.3''+10.8'')/12 \quad 62.1/144 = 14.06 \text{ psi}$	14.13 psi

Comparison of temperature measured by thermometer (TR-2259) and DAS

	thermometer	DAS
Test 1	37°C	37.1°C
Test 2	34°C	34.6°C

The difference did not exceed 1°C which is acceptable.

Comparison of flow measured by the bucket stopwatch technique and the DAS

In the first flow check the weight of water collected was 1749 lb. in 2 minutes 0.19 seconds. The temperature was 21°C. This flow is 104.8 gpm. The Trapeze flow was 105.1 gpm of a difference of 0.3 gpm, which is acceptable.

In the second flow check the weight of water collected was 2001 lb. in 2 minutes 0.20 seconds. The temperature was 20°C. This flow is 119.9 gpm. The Trapeze flow was 120.3 gpm of a difference of 0.4 gpm, which is acceptable.

**DATE
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