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SODIUM FLOW TEST
OF 7-ROD CLUSTER IN SODIUM COMPONENTS
EVALUATION LOOP (SCEL)

September 1969

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SODIUM FLOW TEST OF 7-ROD CLUSTER
IN SODIUM COMPONENTS EVALUATION LOOP (SCEL)

by

M. K. Millhollen

FFTF Fuels Development Department
Fast Flux Test Facility Project

September, 1969

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M. K. Millhollen

ABSTRACT

A flow test was conducted in which a short, 7-rod fuel cluster, contained within a hexagonal flow duct was subjected to flowing, 1060 °F sodium for 9000 hr. Velocity of flow over the 304 SS cladding and wire wrap spacers varied from 25 ft/sec at the beginning of the test period to 30-31 ft/sec at the end. Interim visual examinations were performed when convenient, and a destructive examination of cladding and spacer wire of one rod was conducted after the test. No unusual wear or severe damage was noted at any location. Minor surface damage to both cladding and wire wrap allowed penetration of sodium along grain boundaries to a depth of approximately 0.001 inch.

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SODIUM FLOW TEST OF 7-ROD CLUSTER
IN SODIUM COMPONENTS EVALUATION LOOP (SCEL)

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INTRODUCTION

The initial developmental design effort on an FFTF driver fuel element subassembly revealed that such a subassembly would be composed of a large bundle of relatively small diameter fuel pins arranged in a hexagonal array and separated by a spacing method which would permit cooling of all pin surfaces. It was apparent that coolant velocity over fuel pin surfaces would be in the 30 ft/sec range. Cladding and spacer material favored in December 1966 was 304 SS.

BNW's experience, principally with large diameter spirally wrapped rods, suggested fabrication of a prototypic fuel bundle for coolant pressure drop measurement. A 24-in. long, 7-rod cluster of 0.200 in. diam pins spaced by 0.040 in. diam wire wrap was fabricated for pressure drop testing in water. Since no local information was available on erosion or corrosion of fuel pin end caps, and on wire wraps and cladding in flowing sodium at the proposed sodium coolant temperature and flow velocity, it was decided to follow the water pressure drop tests by a life sodium flow test in the Small Components Evaluation Loop (SCEL). A coolant temperature of 1060 °F coinciding with a calculated fuel pin hot spot temperature was selected for the test. Loop pumps provided a maximum flow velocity in the cluster of 25 ft/sec during the first 5760 hr of the test. These pumps were then replaced with larger units providing a 30 ft/sec flow for the remainder of the test. Coolant impurities were limited to <10 ppm oxygen and <20 ppm carbon. Oxygen was controlled by cold trapping. Great care against introduction of carbon was taken so that the verified limit of less than 20 ppm would not be exceeded.

SUMMARY AND CONCLUSIONS

The 7-rod cluster was placed under test in flowing sodium during CY-1967. The test cluster was examined at irregular intervals and returned to test. The test was terminated after 9000 hr. One pin was cut from the cluster and dimensional measurements were made and compared with those taken prior to assembly. The cladding and wire of the removed pin were cut and prepared for metallographic examination.

At no time during examination was appreciable erosion or corrosion noticed on the pins or wire. The identifying numbers marked on the cladding tube were visible through the next to last inspection (5760 hr) but were no longer visible at the end of the test, an indication that surface erosion was not rapid since the depth of the original marking was approximately 0.0001 inch.

Diametral dimensions were measured at various points on the cut pin and compared with measurements made before flow testing. At no point was there a difference of as much as 0.001 in., nor was the diameter of the wire altered appreciably.

Photomicrographs of polished cross sections of the tube and wire revealed a surface damage zone ~0.001 in. deep within which there appeared to be metallic sodium. Sodium appeared to penetrate along grain boundaries.

This test indicates that erosion or corrosion of fuel pin bundles exposed to hot (1060 °F) flowing sodium is minimal not only when the oxygen content is carefully controlled (<10 ppm), but also at the high flow velocity of 25-30 ft/sec experienced by this test assembly. Therefore, flow velocity and temperature alone within the described range cannot be concluded to cause sufficient damage to 304 SS to preclude its use as fuel pin cladding or spacer material. The test

does not, however, take into account the possible deleterious effects brought about by prolonged exposure to a hard fast neutron flux, or by heat transfer through the surface.

TEST CLUSTER AND SODIUM LOOP

The components of the 7-rod test cluster are shown in Figure 1 (Drawing SK-3-13055). The cluster, 24 in. long, consisted of seven 0.200 in. diam fuel pins spaced in a hexagonal array by 0.040 in. diam wire spirally wrapped on each pin on a 12 in. pitch. Pressed and sintered depleted UO_2 pellets were used to simulate the mass and inertia of $(\text{U,Pu})\text{O}_2$ fuel, and all other components and cladding were 304 SS except the 302 SS internal spring.

The cluster was held in its array by straps welded across the end caps at both the top and bottom of the cluster. End caps on the center fuel pin extended 1/2 in. beyond those of the other pins, thus allowing a spacer arrangement to be welded to the top end cap while a fastening slot was provided in the bottom end cap (Figure 2)

The 7-rod cluster was assembled by slipping it into the specially made, 304 SS hexagonal flow duct to the preselected level where the slot in the center pin bottom end cap was aligned with slits through opposite flats in the hexagonal flow duct. A locking bar was pushed through all three slots and welded to the outer wall of the flow duct at both flats.

The sodium loop used in this test was a small loop located in the 314 Building at BNW. During the first few test runs, the loop was designed to permit lowering of the flow duct with cluster into a large diameter pipe comprising the test section. A special, tightenable arrangement was fastened at the top of the flow duct so that only flow through the flow duct could be discharged. This meant

Neg 0670323

Figure 2. As Fabricated 7-Rod Cluster (Generally Identical to Test Cluster)

that the entire assembly sat within a pool of sodium. The flow duct was centered in the large diameter round pipe by a basket of materials samples attached at the bottom (inlet) end of the flow duct (Figure 3).

Because there was some doubt that the outlet sealing arrangement was completely disallowing bypass flow around the outside of the flow duct, the round pipe test section was removed from the loop after the second test period and the hexagonal flow duct was welded into place as a part of the loop. All of the final testing was conducted in this manner to eliminate possibility of bypass flow.

Loop startup at all times was held to a flow rate of 5 gpm until cold trapping had removed oxygen in excess of 10 ppm from the coolant. Although no hot trap was contained in the loop, carbon analyses showed a content of 20 ppm in the coolant.

After the loop was shut down, the test assembly was removed for inspection and cleaned in Dowanol-EB to remove residual sodium. Then it was immersed in demineralized water for a minimum of 1 hr. The cluster was then air dried and made ready for inspection. All handling was done with clean cotton gloves.

EXPERIMENTAL APPROACH

The flow test in heated, relatively high velocity flow sodium was conducted as an addition to pressure drop tests made on the 7-rod cluster in water. Flow tests of sodium coolant at 1060 °F past wire wrapped fuel pins had not previously been conducted by BNW at a velocity of 25-30 ft/sec. Because the EBR-II flow rates are much lower, a wear problem from either erosion or corrosion was considered possible, and the experience of this test was helpful in planning and scheduling future testing requirements.

Neg 0670943-2
FIGURE 3. Hexagonal Flow Duct with Outlet Flow Director Mechanism at Top
and Sample Basket at Bottom

Since the 314 Building loop (SCEL) had not been previously used, its startup and operation was used to train operators in handling a sodium system. Operator coverage of the loop was maintained over a 24 hr period during the test.

The only requirements placed on the operation were that temperature be maintained within a reasonable range ($1060^{\circ}\text{F} \pm 10^{\circ}\text{F}$), that the oxygen and carbon concentrations be kept below the specified levels, and that flow velocity over the cluster be maintained as close to 30 ft/sec as possible.

Cluster inspections were conducted during opportune periods of loop maintenance down time. At each removal from the test loop, the cluster was cleaned as outlined in Reference 1. Interim inspection was by visual observation only, and no attempt was made to disassemble the cluster. Pictures were taken at each inspection and destructive examination of one pin was conducted at the end of the test.

RESULTS AND DISCUSSION

The SCEL was started up in early April 1967 with the test assembly in place. After an intermittent run of 608 hr, the run was terminated. The test assembly was removed from the loop and cleaned in Dowanol-EB, after which the materials sample basket was cut from the bottom of the flow duct and the 7-pin cluster removed from the flow duct. The latter was accomplished by grinding off the welds joining the locking bar to the flow duct walls.

The appearance of the cluster is shown in Figures 4 and 5. Figure 4 shows the entire 7-rod cluster, while Figure 5 is an enlarged view of the bottom end. In these pictures, the residual film left by an incomplete cleaning process is very evident. The cleaning process was improved for later inspections. Areas of extremely dark surface at places on the pin cladding and end

Neg 0671599-3

FIGURE 4. 7-Rod Cluster After 608 hr in Flowing 1060 °F Sodium

Neg 0671599-1

Figure 5. Bottom End of 7-Rod Cluster

caps also were apparent. These dark areas, although the subject of considerable curiosity at the time, proved to be very thin and difficult to analyze. It was interesting to note that such a film has been observed at other sites working with liquid metal. In the opinion of U.K. workers, this film is associated with areas of cold worked metal and is high in aluminum and calcium content.⁽²⁾

With the exception of the surface coloration, no physical damage was observed at any place on the fuel pins or wires. The cluster was scrubbed in soapy water, rinsed in demineralized water, air dried, and rewelded into the flow duct. The test rig was replaced in the loop and testing was again started.

The second phase of the test run started in May 1967. The loop was shut down during July and August, but the 7-rod cluster was not removed. The run then started again in September 1967, and was continued until November 1967 when the cluster was removed for inspection. At this time, the cluster had accumulated 3430 hr of run time.

The 7-rod cluster was once more removed from the flow duct after cleaning (Figure 6). Most of the black surface film was gone from the fuel pins. Again, no wear or corrosion was evident at any point. Considerable attention was given to the wire wrap at the bottom of the cluster. The wire had been installed by hand and had been overstressed and thinned where it entered the bottom end caps (Figure 7). No evidence of additional thinning or of corrosion at these places was noted. The end cap region at the top of the cluster is shown in Figure 8.

The cluster was rinsed in demineralized water after the examination, dried, and rewelded into the flow duct. Prior to welding the cluster into the flow duct, the duct was modified by removing the special outlet equipment attached to it. The flow duct was welded into the loop as an integral part to insure passage of the entire flow.

Neg 0673720-1

FIGURE 6. 7-Rod Cluster After 3430 hr Exposure to 1060 °F Sodium
Coolant at Flow of 25 ft/sec

Neg 0673720-2

Figure 7. Bottom End of Test Cluster After 3430 hr

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Figure 8. Top End of Test Cluster After 3430 hr

In December 1967, the loop was again started up. After cold-trapping oxygen in the sodium, the loop was brought to full flow velocity of 25 ft/sec at 1060 °F. The loop was operated into March 1968 before it was again shut down for test element inspection.

The flow duct was cut from the loop and cleaned in Dowanol-EB and the test cluster removed. The cluster, as seen in Figure 9, showed no signs of wear or disarray despite the 5760 hr of testing experienced by this time. The individual pin numbers which had been grit blasted onto the surface of the pins were still visible. Surface erosion was deduced to be somewhat less than the 0.0001 in. depth typically penetrated by grit blasting. The wire was still tight and not discernibly thinned. The bottom of the cluster is shown in Figure 10.

During this inspection period, larger pumps were installed in the test loop to permit increased flow velocity. The 7-pin cluster was rinsed in demineralized water, air dried, welded into the flow duct, and the flow duct again welded into the loop. The loop was returned to service in June 1968 with the flow rate adjusted to a velocity through the 7-pin bundle of 30-31 ft/sec at 1060 °F.

Loop operation was continued without incident until late October, 1968, when the 9000-hr test run was completed. The usual removal and cleaning steps were taken. The pin cluster with 9000-hr flow at 1060 °F exhibited no readily apparent erosion or corrosion (Figure 11). The wire wrap appeared looser (Figure 12) and a 0.010 in. thick feeler gage could be pushed between the wire and cladding. Whether this looseness was caused by the increased velocity of the flow or by a relaxation from the overstressed condition at fabrication is impossible to assess. It was also noted that the grit blasted pin numbers were no longer visible on the pin surfaces, thus indicating a possible increase in surface erosion with the

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FIGURE 9. 7-Rod Cluster After 5760 hr in Flowing 1060 °F Sodium

Neg 0680856-2

Figure 10. Bottom End of 7-Rod Cluster

Neg 0683903-4
FIGURE 11. 7-Rod Cluster After 9000 hr in Flowing 1060 °F Sodium

Neg 0683903-1
FIGURE 12. Bottom End of 7-Rod Cluster After 9000 hr in Flowing
1060 °F Sodium (Note loosened wire wrap)

increase in flow velocity. The top of the assembly exhibited no particular changes (Figure 13). One pin was scraped when the cluster was removed from the flow duct. The cleaning method had been well perfected at this time as can be seen in the photographs.

Measurements were made at various places along the pins and wires of the bundle and at the welds. At no place was a diametral change of as much as 0.001 in. measured. There was no local decrease in wall thickness of the cladding under the wire wrap, although the pattern of the wire location on the outside of the pin tubing was barely visible as a faint shadow after the wire had been removed.

One pin (B-18) was cut from the cluster for further study. The wire was cut off the pin and diametral measurements, coinciding with pretest measurements, were made on the pin. Wire diameter measurements were also made (Table 1).

The pin was then sectioned through the cladding, through an end cap weld and a wire weld, and then examined metallographically. A wire wrap cross-section was also prepared and examined. Control pieces of wire wrap and cladding tubing not previously exposed to sodium or elevated temperature were also prepared.

Photomicrographs of the control wire and cladding tubing are compared to photomicrographs of the tested wire and cladding tubing in Figures 14, 15, 16, and 17. Typical 304 SS grain structure is evident in the control samples while carbide precipitation in the grain boundaries, as well as sodium penetration at locations along grain boundaries, is immediately evident in the tested material. Figure 18 shows a cross-section through a wire-to-end cap weld. Evidently, the weld did not completely bond the entire wire end to the end cap but it held. The tubing to end cap weld cross-section shown in Figure 19 shows a smeared, carbide precipitation condition in the heat affected zone.

TABLE 1. *Rod B-18 Wire Wrap Measurements*

<u>Before Test</u>	<u>After Test</u>
<u>Fuel Rod Diameter, in.</u>	
0.1991	0.1988
0.1992	0.1992
0.1992	0.1990
0.1992	0.1989
0.1992	0.1992
0.1992	0.1993
0.1992	0.1990
0.1992	0.1992
0.1993	0.1991
0.1992	0.1990
<u>Wire Diameter, in.</u>	
0.0404	0.0401
0.0405	0.0402

Neg 0683903-3

Figure 13. Top End of 7-Rod Cluster (9000 hr)

Neg 468-2464B

250X

Control Sample

Neg 468-2467B

250X

Tested Sample

Neg 468-2467C

500X

Tested Sample

FIGURE 14. Comparison of High Magnification Photomicrographs of Control and Tested 304 SS Wire Wrap.

Neg 468-2464A

75X

Control Sample

Neg 468-2467A

75X

Tested Sample

FIGURE 15. *Comparison of Low Magnification Photomicrographs of Control and Tested 304 SS Wire Wrap.*

Neg 468-2465A 75X
Control Sample

Neg 468-2468A 75X
Tested Sample

FIGURE 16. Comparison of Sections of Control and Tested Cladding Showing Changes in Grain Boundary Delineation

Neg 468-2465B

Control Sample

250X

Neg 468-2468B

Tested Sample

250X

Neg 468-2468C

Tested Sample

500X

FIGURE 17. *Comparison of Control Cladding to Cladding Tested 9000 hr in Flowing 1060 °F Sodium*

Neg 568-2471

75X

Figure 18. Wire Weld in End Cap After 9000 hr in Flowing 1060 °F Sodium

Neg 468-2470

75X

Figure 19. Cladding-To-End Cap Weld Area After 9000 hr in Flowing 1060 °F Sodium

To further show that there was no selective cladding surface damage beneath the wire wrap, tubing samples were prepared metallographically with the location of the wire wrap indicated. As can be seen in both the pre- and post-etched pictures, no special damage occurred at that point. The general 0.001 in. depth surface damage was evident at all points around the circumference of the cladding tube (Figures 20 and 21).

Because the cluster was hand fabricated to allow rapid collection of water flow pressure drop data, no thought was given at that time to subjecting the cluster to a life test in flowing sodium. The important detail of overstressing the wire wrap has contributed confusion to the interpretation of the results. Too, the lack of adequate pumping capacity holding the coolant flow to ~25 ft/sec, below the desired value of 30 ft/sec, for much of the test may have permitted misinterpretation of results.

Generally, the results of the test indicate that corrosion and erosion are not important problem areas on sodium cooled, 304 SS fuel pin bundles. Further information will be forthcoming when the 217-pin bundle of 0.250 in. diam fuel pins spaced by spirally wrapped 0.030 in. diam wire has completed its test period in the CCTL.

Neg 469165A

Unetched

100X

Neg 469165B

Etched

100X

Figure 20. *Cladding Directly Under Wire Wrap After 9000 hr in Flowing 1060 °F Sodium*

Neg 469165G

Unetched

100x

Neg 469165H

Etched

100X

FIGURE 21. *Cladding at 90° from Wire Wrap After 9000 hr in Flowing 1060 °F Sodium*

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The author wishes to thank R. M. Crawford who managed the fabrication of the cluster and F. B. Quinlan who fabricated the specially-sized hexagonal flow duct for their major contributions to the test. The effective operation of, modification to, and data collection from the loop was efficiently controlled by M. O. Rau, M. E. Shockley and J. D. Smith. Metallography was conducted by the Metallography Unit under the direction of L. A. Hartcorn.

REFERENCES

1. L. E. Chulos, Sodium Removal and Cleaning of Reusable Hardware, BNWL-637. Battelle-Northwest, Richland, Washington, December 1967.
2. J. A. Bray, R. Hardman, and J. M. Simpson. Endurance and Thermal Shock Tests on a DFR Mark-2 Subassembly in Flowing NaK. TRG-Report-1181(D), Risley, 1966.

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