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FABRICATION OF MARK II PROTOTYPIC
FFTF FUEL SUBASSEMBLY
FOR SODIUM FLOW TEST

R. L. Myers

June 1970

AEC RESEARCH &
DEVELOPMENT REPORT

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FFTF FUEL SUBASSEMBLY
FOR SODIUM FLOW TEST

By

R. L. Myers

FFTF Fuels Department
FFTF Division

June, 1970

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ABSTRACT

A prototypic model FFTF Mark II fuel subassembly was built and shipped to the Argonne National Laboratory in Argonne, Illinois, to undergo sodium flow testing for 9000 hr in the Core Components Test Loop. The subassembly was comprised of 217 fuel pins assembled into a hexagonal array with top and bottom grid arrangements holding the pin bundle inside a hexagonal flow duct. The pins were 0.230 in. diameter by 90 in. long and each was wrapped with a 0.056-in. diameter 20% cold-work wire on a 12-in. pitch. All materials in the pin bundle in contact with sodium were of Type 316 SS. The duct and nosepiece material was Type 304 SS.

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INTRODUCTION

A Mark I prototypic FTR fuel element subassembly has been tested in the Core Components Test Loop at the Argonne National Laboratory.⁽¹⁾ Since the FFTF fuel subassembly design has changed significantly from that of the Mark I, a second long-term test was desired by the design staff. This second subassembly, the Mark II, was fabricated for sodium flow testing in the CCTL. The purpose of the Mark II fuel subassembly test is to provide design verification for the FFTF driver fuel assembly and to identify such potential long-term failure modes as wear corrosion rates, structural damage, and others.

This report contains a description of the test assembly design, fabrication procedures, shipping, and quality assurance programs. All of the fabrication methods are not discussed in the text, but specific details are included in the appendices. An archive file of data including design drawings, design changes, inspection data, characterization data, pictures and other related items is being kept by BNW for comparison analysis during post-test examinations.

SUMMARY

A full-scale model of an FFTF Mark II fuel subassembly was built and shipped to the Argonne National Laboratory for flow testing in the Core Components Test Loop. The design for this subassembly is prototypical of the FFTF driver fuel subassembly, except for some deviations which have been allowed to either simulate reactor operating conditions, allow easier fabrication, or to shorten the fabrication schedule.

The top grid and wire wrap attachment designs were not agreed upon until late January, 1970. Standard fabrication techniques were used except in cases where new designs made it necessary to develop new procedures or alter established ones. Significant development work included setting new parameters for bottom end-cap welding, establishing a vertical loading procedure for a small cladding-pellet gap, developing a welding technique for the lower grid plates, and developing duct-nosepiece components welding procedures. A quality assurance program was used to verify conformance of each component and the completed subassembly to design requirements and document all deviations. The completed subassembly was crated and shipped to ANL on February 25, 1970.

DISCUSSION

A second prototypic fuel subassembly has been fabricated for sodium flow testing in Argonne National Laboratory's Core Components Test Loop (CCTL) in Chicago. The fuel assembly, CCTL Mark II, was designed and built to reflect the most current FFTF driver fuel assembly design. For convenience, the description of the fabrication of the subassembly is divided into three parts: fuel pin fabrication, pin bundle fabrication, and subassembly fabrication. A quality assurance program was established to provide material control and inspection of component parts. The completed fuel assembly was packaged and shipped via truck and air freight.

DESIGN

The overall test requirements and design requirements are given in the CCTL Mark II Engineering Test Plan⁽²⁾ and the following drawings, which are shown in Appendix C.

SK-3-14696	Rev. 5	CCTL Nosepiece
SK-3-15089	Rev. 3	CCTL Fuel Duct

SK-3-15240	Rev. 7	CCTL Mark II Duct Assembly
SK-3-15242	Rev. 4	CCTL Driver Fuel Subassembly
SK-3-15243	Rev. 7	CCTL Driver Fuel Pin Assembly and Details
SK-3-15244	Rev. 5	CCTL Driver Fuel Locking and Spacer Grid Details

The assembly was built to reflect the most current FFTF driver fuel assembly design, insofar as this was practical and possible. Some unresolved designs were the subject of considerable discussion among BNW, Westinghouse, and the USAEC, which resulted in significant delays of the fabrication schedule.

Two deviations from the prototypic design were made to simulate conditions anticipated during reactor operation: (1) the fuel pellet diameter was increased to minimize the pellet-cladding gap, and (2) the flow duct was expanded to increase the bundle-duct gap. Other minor deviations from the reference fuel assembly design were made when there would be a negligible effect on the test and advantages in fabrication or schedule would be realized. These deviations have been documented and were approved either by design in the engineering test plan or by waiver.

FABRICATION

Standard fabrication techniques and procedures were used where possible and these will not be discussed in detail. Some development work was necessary to determine new procedures and parameters and these will be discussed along with design deviations for each component. The fuel pin components were fabricated and assembled into fuel pins. The pins were then assembled with the top and bottom grids into a bundle; and this fuel bundle, flow duct, nosepiece, and associated hardware made up the fuel subassembly.

Fuel Pin

The fuel pin components are shown in Drawing SK-3-15243 in Appendix C. The fuel pellets were made using natural UO_2 in place of $\text{UO}_2\text{-PuO}_2$ since the CCTL flow test is an out-of-reactor test. The insulator pellet lengths were made identically to those of the fuel pellets, resulting in a fuel column length of 37 in. containing no insulator pellets. The pellet diameter was increased from 0.194 in. to 0.1970 ± 0.0005 in. to simulate the cladding-pellet gap under reactor operating conditions. Considering allowable tolerances, the pellet-cladding gap was expected to range from 0.0021 to 0.0032 in. The pellet lengths and diameters were controlled using a sampling inspection plan.

The fuel pin internal components, starting at the bottom end, were comprised of: six 1-in. long reflector rods, 37 in. of natural uranium pellets, six 1-in. long reflector rods, and plenum hardware consisting of a plenum spring, plenum tube, and a plenum tube plug. The plenum hardware measured 40.5 in. in length.

The first assembly step in fabricating the pins was welding the bottom end-caps to the cladding (Figure 1)'. Because of the new design of the bottom end-caps, some development work was necessary to establish weld parameters. These parameters and the welding procedure are described in the Appendix D. The end-cap welds were 100% radiographed and the reject rate was 26/273 or 9.5%. At the completion of bottom end-cap welding, there were 247 acceptable pins (partially fabricated).

The close pellet-cladding gap made it necessary to load the pins in the vertical position. The new loading procedure was developed and is described in the Appendix D. The fuel

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FIGURE 1. End Cap Welding

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column was weighed and loaded in 6-in. increments. Each 6-in. increment was seated to eliminate any gaps between pellets (Figures 2 through 4). A length gage was used to measure the length of the fuel column (Figure 5). Because of the small pellet-to-cladding gap some pins were rejected during the loading operation. These pins were rejected at a rate of 3% (7/247), leaving 240 acceptable pins after the loading operation.

The top end-cap design was not determined until late January, 1970, and this resulted in an approximate 3-month delay in the fabrication schedule. The design eventually remained unchanged, although the top grid was extensively modified. The plenum springs and tubes were loaded prior to welding the top end-caps into place. After welding, all pins were subjected to and passed a helium leak test. Radiography plus a visual check of the top end-cap welds resulted in a reject rate of 5% (12/240). The full length of all pins was also radiographed to ensure the proper placement of internal components.

After the top end-cap welding operation, there were 228 acceptable pins. Thirty-seven of these pins were characterized by recording the following data: fuel pin and wire wrap diameters at 9-in. intervals, profilometer measurements of the bare pin, and fuel pin length and weight measurements.

Each pin was wrapped with a 0.056-in. diameter Type 316 SS 20% cold work wire (Figures 6, 7, and 8). The wire was attached at each end cap with a 3/32-in. fillet weld. The wire wrap procedure is included in Appendix D. The weld design was the subject of extensive discussion involving three basic designs: the 3/32-in. straight fillet weld, a 90 degree bend through the end cap, and a 45 degree bend through the end cap. Other designs were also proposed, but

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FIGURE 2. Fuel Pellet Weighing

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FIGURE 3. Fuel Pellet Loading

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FIGURE 4. Fuel Pellet Seating

NEG 700273-6

FIGURE 5. Fuel Pellet Column Length Measurement

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FIGURE 6 Wire Wrap Set Up

NEG 700611-5

FIGURE 7. Wire Wrapping

NEG 700611-8

FIGURE 8. Removal of Fuel Pin from Wire Wrap Machine

BNWL-1418

agreement on the straight fillet weld was reached by BNW, Westinghouse, and the USAEC. A study of various wire wrap weld designs was performed as a result of these discussions and are reported under a separate cover. (3,4)

All wire wrap welds were radiographed, but these were not read for penetration or fusion because of the difficulties of interpreting the results. The reject rate was 2.6% (6/228), with the rejects resulting from damaged wire, inclusion, and cracks. A summary of fuel pin inspections and acceptance rates is listed in Table 1.

TABLE 1. Fuel Pin Inspection Acceptance Rates

<u>Type of Inspection</u>	<u>Acceptance Rate, %</u>
Radiography	
Bottom End Cap Weld	90.5
Top End-Cap Weld	95
Full Length	100
Wire-Wrap Weld	97.4
Helium Leak Check	100
Loading	97
Overall (222/273)	81.4

Pin Bundle

The lower grid assembly consisted of the lower grid frame, 17 grid plates, and 3 support bars. The fabrication of the plates required a development program to select a method for welding the round rails to the plates. An electron beam welding technique was chosen, the weld parameters were determined, and sample welds (Figure 9) were tested for strength and quality. These parameters and a report on the development work is included in Appendix E.

Two changes in design of the lower grid assembly were made. One change increased the height of the support bars

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FIGURE 9

Lower Grid Plate Electron Beam Weld

BNWL-1418

(and, therefore, the plates and frame) to ensure adequate strength during the flow test. The other change, which simplified fabrication of the support frame, required four welds (one in each corner) as opposed to bending each corner and making one weld on a flat.

A number one was marked on the lower grid frame to correlate with the duct identification number stamped on the corresponding duct flat. These numbers will facilitate correlation between bundle and duct flats during post test analysis.

The fuel pins were assembled into strip layers by pinning the bottom end caps to the lower grid plates (Figures 10 and 11), and these strip layers were then assembled into a fuel bundle (Figures 12 and 13). Thirty of the characterized pins were assembled in predetermined locations in the bundle. Seven extra characterized pins were located randomly throughout the bundle. Figure 14 is a chart of the pin positions in the subassembly and shows the strip layer numbers, pin and tube numbers, the position of the characterized pins, and the orientation of the pin bundle with the flow duct.

The approved design for the top grid assembly was received in the latter part of January, 1970. The top grid assembly was welded together (Figure 15) and put in place on the hexagonal array of pins. This process proved to be long and tedious because of the problems of lining up all 217 pins.

One of the requirements for this test subassembly was a compressibility test. This test was performed in a specially built compressibility test fixture (Figure 16) and the results are included in Appendix B.

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FIGURE 10. Strip Layer Assembly

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FIGURE 11. Strip Layers

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NEG 700642-6

FIGURE 12. Pin Bundle Assembly

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FIGURE 13. Partially Assembled Pin Bundle

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FIGURE 14. CCTL Mark II Pin Location Map

BNWL-1418

NEG 700611-3

FIGURE 15. Top **Grid** Frame

NEG 700642-5

FIGURE 16. Compressibility Test Fixture

Subassembly

The hexagonal flow duct, originally fabricated to the reference design, was expanded from an inside dimension across flats of 4.335 to 4.354 ± 0.005 in., which is 0.054-in. beyond the actual tight bundle dimension (based on actual measurements of pin and wire diameters). This variation in design provides for duct-bundle gap that is anticipated during reactor operation. A backup duct, labeled No. 8 on the material certification, was used in place of the one originally planned because of a machining error on No. 1. The duct was stamped with a number 8 near the lower grid support bar welds on the flat corresponding to the number 1 marked on the lower grid frame. The duct was characterized by taking outside measurements across flats and corners at various points along the length, wall thickness at each end, twist, and bow measurements. The duct was loaded over the bundle (Figure 17) and the top and lower grids welded into place. The entire assembly was then placed on a granite table where final welding and characterization were performed. The duct and final subassembly characterization data are contained in Tables A.2 and A.3 in Appendix A.

The nosepiece (Figure 18) parts were fabricated according to SK-3-14696 (Appendix C). A development program using sample pieces to determine welding techniques and parameters was completed prior to welding the actual test assembly components.

Argonne National Laboratory furnished four components of the subassembly--the spherical seal, two guide rings, and the top flange. The spherical seal was fabricated to a design calling for a 0.060 in. larger bore, resulting in a loose fit on the inlet piece. This situation was corrected by welding a sleeve to the inner diameter of the seal and then welding the

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FIGURE 17. Duct Assembled Over Bundle

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FIGURE 18. Nosepiece Assembly

seal to the nosepiece. The nosepiece was then welded to the duct using a technique of welding on opposite sides and checking the position of the end plug to maintain alignment as accurately as possible.

The rest of the hardware--two ring flanges, one top flange, four pressure tap pipes and bosses, and four accelerometer studs--were welded in place (Figures 19, 20, and 21) and additional characterization data were obtained. This fuel subassembly was then ready for packaging and shipping (Figure 22).

SHIPPING

The completed assembly was wrapped in plastic and crated in a wooden shipping container built to meet DOT (formerly ICC) Specification 15 B, Section 78.169. Four accelerometers were attached to the sides or wooden struts on the inside of the shipping container to obtain information about the magnitude of forces transmitted to an assembly during shipping. The data from these instruments are shown in Table A.4 in the Appendix A. This container was placed inside a second wood box, with a resilient padding in between the two boxes.

The Mark II fuel subassembly was shipped on February 25, 1970, by truck from Richland to Portland and by air from Portland to Chicago via San Francisco. A BNW representative escorted the shipment to Portland and one was present at San Francisco and Chicago to observe the handling of the shipment. No abnormal shocks, drops, or rough treatment were reported.

A follow-up study was conducted to determine the effects of dropping a simulated CCTL Mark II subassembly and shipping crate. The test and results are summarized in Appendix G.

QUALITY ASSURANCE

A quality assurance program was used to verify conformance of each component to design requirements and document any

FIGURE 19. Spherical Seat and Nosepiece-Duct Welds

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FIGURE 20

Guide Ring, Lower Support Bars, and Pressure Tap Welds

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FIGURE 21 Top Flange, Pressure Tap, and Top Grid Duct Welds

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FIGURE 22 Completed Subassembly

deviations. All materials used were certified and traceability was maintained through the fabrication, inspection, and assembly processes. All components fabricated or assembled outside of the FFTF Fuels Department were inspected for conformance to design specifications. All nonconforming items were either refabricated, reworked, or approved in the as-built condition by waiver at Technical Review Board meetings. All design deviations and inspection data are recorded and will be kept for comparison with post-test inspection data. An archive sample of each component part, where possible, and two complete fuel pins are being kept for similar comparisons.

Fuel pin follower cards were generated at the beginning of assembly of each pin. All of the assembly processes and required inspection data are recorded on these cards. Rejected pins were separated from the acceptable pins which continued through the assembly process.

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APPENDIX A
CHARACTERIZATION DATA

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TABLE A.1. Pin Characterization Data

<u>Wire No.</u>	<u>Tube No.</u>	<u>PIN DIAMETERS, IN.</u>			<u>WIRE DIAMETERS, IN.</u>		
		<u>Average</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>	<u>Maximum</u>	<u>Minimum</u>
14	29-096	0.2298	0.2299	0.2297	0.0560	0.0560	0.0559
32	29-088	0.2298	0.2301	0.2297	0.0560	0.0561	0.0559
10	29-019	0.2299	0.2300	0.2298	0.0560	0.0560	0.0559
2	29-165	0.2298	0.2299	0.2297	0.0562	0.0563	0.0561
9	29-159	0.22985	0.2299	0.2298	0.0563	0.0564	0.0563
16	29-184	0.2299	0.2302	0.2299	0.0560	0.0560	0.0559
1	29-120	0.2297	0.2298	0.2297	0.0560	0.0560	0.0559
8	29-066	0.2299	0.2299	0.2298	0.0560	0.0560	0.0559
	29-142	0.2298	0.2299	0.2297			
15	28-130	0.2298	0.2299	0.2298	0.0562	0.0563	0.0561
36	29-087	0.2298	0.2301	0.2297	0.0562	0.0562	0.0562
26	28-073	0.2298	0.2298	0.2297	0.0560	0.0561	0.0559
22	28-080	0.2298	0.2299	0.2298	0.0560	0.0560	0.0560
29	29-030	0.2299	0.2301	0.2299	0.0562	0.0562	0.0561
38	29-122	0.2299	0.2299	0.2298	0.0562	0.0563	0.0562
	28-082	0.2297	0.2298	0.2297	-----	-----	
35	28-096	0.2298	0.2298	0.2297	0.0560	0.0560	0.0560
19	28-059	0.2298	0.2299	0.2297	0.0560	0.0560	0.0559
25	28-097	0.2298	0.2299	0.2297	0.0559	0.0560	0.0559
18	29-063	0.22975	0.2299	0.2297	0.0560	0.0560	0.0560
37	29-170	0.2297	0.2299	0.2297	0.0560	0.0560	0.0560
4	29-049	0.2298	0.2300	0.2298	0.0560	0.0561	0.0560
23	29-004	0.2299	0.2300	0.2298	0.05605	0.0561	0.0560
5	29-128	0.22975	0.2299	0.2296	0.0560	0.0561	0.0560
30	29-082	0.2300	0.2300	0.2299	0.0560	0.0561	0.0559
27	29-158	0.2298	0.2299	0.2298	0.0560	0.0561	0.0560
34	29-077	0.2293	0.2299	0.2298	0.0560	0.0560	0.0559
40	29-129	0.2299	0.2300	0.2298	0.0560	0.0561	0.0559
17	29-078	0.2298	0.2298	0.2297	0.0562	0.0563	0.0562
39	29-164	0.22985	0.2300	0.2298	0.0560	0.0560	0.0560
21	29-040	0.2300	0.2302	0.2300	0.0560	0.0561	0.0560
13	28-061	0.2298	0.2298	0.2298	0.562	0.563	0.0561
28	28-002	0.2297	0.2298	0.2297	0.0560	0.0561	0.0559
6	29-037	0.2298	0.2299	0.2298	0.0560	0.0562	0.0560
20	29-167	0.2298	0.2300	0.2298	0.0560	0.0560	0.0560
31	29-073	0.2298	0.2299	0.2297	0.0560	0.0560	0.0560
24	29-174	-----	-----	-----	0.0560	0.0561	0.0560
1	29-132	-----	-----	-----	0.0560	0.0560	0.0559

TABLE A.2. **Duct Characterization - Test CCTL Mark II**

Measurements, Outside Across Flats, in.

	<u>1a</u>	<u>1b</u>	<u>1c</u>	<u>2a</u>	<u>2b</u>	<u>2c</u>	<u>3a</u>	<u>3b</u>	<u>3c</u>	<u>1-2</u>	<u>2-3</u>	<u>3-4</u>
TOP	4.6465	4.653	4.652	4.641	4.651	4.642	4.650	4.650	4.646	5.243	5.245	5.250
3 ft	4.645	4.646		4.641	4.6425		4.644	4.641				
6 ft	4.645	4.646		4.638	4.638		4.643	4.640				
9 ft	4.644	4.644		4.640	4.641		4.645	4.644				
BOTTOM	4.643	4.644	4.644	4.640	4.641	4.642	4.645	4.643	4.644	5.239	5.248	5.248

Measurement, Wall Thickness - Top, in.

1 a	0.144	2a	0.145	3a	0.143	4a	0.146	5a	0.145	6a	0.145
b	0.140	b	0.145	b	0.144	b	0.145	b	0.146	b	0.141
c	0.144	c	0.144	c	0.145	c	0.143	c	0.146	c	0.1415

Measurement, Wall Thickness - Bottom, in.

1 a	0.144	2a	0.144	3a	0.144	4a	0.142	5a	0.145	6a	0.145
b	0.140	b	0.144	b	0.143	b	0.144	b	0.145	b	0.146
c	0.143	c	0.144	c	0.142	c	0.144	c	0.145	c	0.144

TABLE A.3. Final Characterization - Test CCTL Mark II

Measurement Outside Across Flats, in.													
		1a	1b	1c	2a	2b	2c	3a	3b	3c	1-2	2-3	3-4
TOP		4.638	4.658	4.636	4.649	4.664	4.652	4.652	4.668	4.652	5.235	5.249	5.237
f t	in.												
1	8 1/2	4.638	4.637	4.646	4.657	4.653	4.657	4.639	4.665	4.664	5.236	5.265	5.250
1									4.646				
3	9								4.640				
4	4							4.648	4.647	4.645			
6	3								4.640				
8									4.643				
									4.645				
8	6							4.646	4.647	4.645			
10	6	4.645		4.644	4.628	4.624	4.654	4.656	4.661	4.656	5.205	5.256	5.231
BOTTOM		4.614	4.613	4.618	4.624	4.654	4.656	4.661	4.656	5.205	5.256	5.231	

Measurements, <u>BOW</u> , in.							
Shim = 2 1/2 in. (2 blocks under duct)							
		Flat 1	Flat 2	Flat 3	Flat 4	Flat 5	Flat 6
2 in.		+0.016	+0.033	-0.020	+0.050	+0.012	+0.052
6 in.		+0.053	+0.025	-0.007	+0.004	+0.036	+0.063
BOTTOM		+0.019	+0.067	0.000	+0.026	-0.003	-0.013
END OF NOSECONE		4 13/16	4 11/16	4 11/16	4 13/16	4 29/32	5
TOP		0.000	+0.0005	+0.003	+0.016	+0.014	-0.011
3 f t		-0.001	+0.008	+0.001	-0.005	+0.005	+0.010
5 f t		+0.015					
6 f t		+0.008	+0.007	-0.001	-0.009	-0.007	+0.019
9 f t		+0.009	-0.002	+0.001	-0.010	+0.021	+0.030
BOTTOM		+0.002	+0.018	-0.013	-0.002	+0.007	+0.011

TABLE A.4. **Weight of CCTL Mark II Subassembly**

<u>Components</u>	<u>g</u>
217 Pins (217 × 405)	87,900
217 End-Cap Pins	12
Lower Grid Assembly	824
Nosepiece (1)	7,683
Spherical Seat (1)	2,867
Duct Cap (1)	3,074
Duct Rings (2)	1,924
Bosses (4)	25
Pipes (4)	18
Top Grid Assembly (est.)	800
Duct 83 lb =	37,600
Weld Studs (4) (est.)	<u>25</u>
	142,752
1000 g = 2.205 lb	
$142,752 \text{ g} \times 2.205 \times 10^{-3} \frac{\text{lb}}{\text{g}} = 315 \text{ lb}$	<u>315 lb</u>
Shipping Container	<u>182 lb</u>
Gross Weight	497 lb

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APPENDIX B

COMPRESSIBILITY TEST RESULTS

FIGURE B.1. Summary Mark II Compressibility Tests

B-2

FIGURE B.2. Mark II Compressibility Test - Run No. 1

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B-3

FIGURE B.3. Mark II Compressibility Test - Run No. 2

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B-4

FIGURE B.4. Mark II Compressibility Test - Run No. 3

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APPENDIX C
DESIGN DRAWINGS

FIGURE C.1 CCTL Nosepiece

SK-3-15089 Rev. 3

FIGURE C.2 CCTL Fuel Duct

SK-3-15240 Rev

FIGURE C.3. CCTL Mark II Duct Assembly

SK-3-15242 Rev. 4

FIGURE C.4. CCTL Driver Fuel Subassembly

QTY	PT NO	DESCRIPTION	MAT L
✓	1	ASSEMBLY	
✓	2	ASSEMBLY	
1	3	END CAP - TOP H-3-29540	316 SST
1	5	END CAP - BOTTOM	316 SST
1	6	SPRING	
AR	7	INSULATOR PELLET	MAT. UO ₂
	8		
	9		
1	10	PLUG	316 SST
	11		
12	12	ROD - 0.194 ± 0.001 O.D. x 1.000 LG. ± 0.01	316 SST
1	13	TUBE - 0.230 ± 0.001 O.D. x 0.200 ± 0.001 I.D. x 90.000 ± 0.015 LG	316 SST
AR	14	WIRE - 0.056 ± 0.005 DIA	316 SST
AR	15	FUEL PELLET SIMULATED	

<u>TYP</u>	<u>PIECE</u>	<u>MARK</u>
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10
11	11	11
12	12	12
13	13	13
14	14	14
15	15	15
16	16	16
17	17	17
18	18	18
19	19	19
20	20	20
21	21	21
22	22	22
23	23	23
24	24	24
25	25	25
26	26	26
27	27	27
28	28	28
29	29	29
30	30	30
31	31	31
32	32	32
33	33	33
34	34	34
35	35	35
36	36	36
37	37	37
38	38	38
39	39	39
40	40	40
41	41	41
42	42	42
43	43	43
44	44	44
45	45	45
46	46	46
47	47	47
48	48	48
49	49	49
50	50	50
51	51	51
52	52	52
53	53	53
54	54	54
55	55	55
56	56	56
57	57	57
58	58	58
59	59	59
60	60	60
61	61	61
62	62	62
63	63	63
64	64	64
65	65	65
66	66	66
67	67	67
68	68	68
69	69	69
70	70	70
71	71	71
72	72	72
73	73	73
74	74	74
75	75	75
76	76	76
77	77	77
78	78	78
79	79	79
80	80	80
81	81	81
82	82	82
83	83	83
84	84	84
85	85	85
86	86	86
87	87	87
88	88	88
89	89	89
90	90	90
91	91	91
92	92	92
93	93	93
94	94	94
95	95	95
96	96	96
97	97	97
98	98	98
99	99	99
100	100	100

GENERAL NOTES

ALL PARTS, UNLESS OTHERWISE SPECIFIED, SHALL CONFORM TO THE FOLLOWING:

- 1-TOLERANCES, FRACTIONAL $\pm \frac{1}{64}$, DECIMAL $\pm .005$, ANGULAR $\pm 0^{\circ} 30'$
- 2-REMOVE ALL BURRS AND BREAK SHARP EDGES TO $\frac{1}{64}$ MIN RADIUS, EXCEPT WELD PREP AREA (TUBE ENDS & LIPS)
- 3-ALL MACHINED SURFACES $\sqrt{32}$ SURFACE ROUGHNESS SHALL BE IN ACCORDANCE WITH U S A S I B 46.1 (LATEST REV)
- 4-DIMENSIONS & TOLERANCES IN ACCORDANCE WITH USASI Y-14.5-1966
- 5-MATERIAL 316 S S T SPECIFICATION HWS-1001
- 6-FUEL PIN SHALL SHOW A MAXIMUM RCW NOT TO EXCEED .010 PER LINEAL FOOT. TOTAL FOR PIN NOT TO EXCEED .025.
- 7-END CAP WELD DIAMETER SHALL NOT PROJECT MORE THAN .003 BEYOND THE TUBE DIA.
- 8-PELLET LENGTH TO DIAMETER RATIO SHALL BE $.75 \leq \frac{L}{D} \leq 2.0$
- 9 REFERENCE POINTS FOR WIRE TWIST START & STOP
- 10-END CAP PLUGS SHALL BE MACHINED TO FIT TUBE. PLUG DIAMETER SHALL BE 0.0007 TO 0.0013 LESS THAN TUBE INNER DIAMETER.
11. 308 SST FILLER MATERIAL SHALL BE USED IN WIREWRAP TO END CAP FILLET WELDING

FIGURE C.5. CCTL Driver 1 Pin Assembly Details

APPENDIX D
FABRICATION PROCEDURES

CCTL MARK II OPERATING PROCEDURELOWER END-CAP WELDINGPurpose

To produce high-quality, reliable welds for fuel pin end closures. This is to be accomplished by the use of a carefully controlled welding procedure.

Equipment

- (a) Tube welding head and fixture (Drawing H-3-15284)
- (b) Welding power supply
- (c) Shaded welding glass No. 10 for eye protection
- (d) Stainless steel wire brush (0.006 max wire diameter)
- (e) Wire brushing fixture.

Materials

- (a) Cladding
- (b) Argon 25% - Helium 75% mixed gas
- (c) Lower end caps (SK-3-15243)
- (d) Tungsten 2% thoriated electrodes

Procedures

1. Set weld sequence programmer for the attached welding (No. 19) procedure.
2. Check programmer timing devices using a stop watch.
3. Check rotation of tube or welding heat with stop watch.
4. Check gas supply and flow.
5. Parts shall be cleaned prior to assembly and insertion into the welding tooling, Cladding shall be cleaned according to the attached cleaning procedure. End caps shall be cleaned in an ultrasonic tank with alcohol for 15 minutes.
6. Fit between the tube and end-cap is carefully checked at assembly.

7. Complete weld to be in accordance with established welding procedure (No. 19).
8. Wire brush weld to remove oxide formed during welding if specified by Fabrication Engineer. Wire brushing shall be accomplished using a stainless steel wire brush with the wire diameter not exceeding 0.006 in. in diameter. Pressure on the part during brushing shall be controlled by the use of the wire brush fixture, so that no more than 0.0005 in. is removed from the OD of the tube.
9. A weld sample shall be taken after every 25 welds.
10. Completed welds will be inspected visually and helium leak tested. Thirty-five completed welds to be radiographed.

NOTE: Weld samples shall be a 6-in. length of cladding from the same lot as the pins being fabricated. End caps shall be selected from those being processed.

WELDING PROCEDURE

Project: CCTL Mark II
Lower End Caps

Process: T.I.G.

Alloy: Type 316 SS

Power Source: Merrick E.S.R. 300
(USA HW522979)

Torch: HWS20 (Welding Head)

Cup: Gas Screen No. 4 Cup

Shielding Gas: He-A
Type: 75% to 25%
Volume: 60 CFH

Electrode:
Type: 2% Thoriated Tungsten
Diam: 1/16 in.
Ext.: 0.250 in.
Shape: 30 degrees

Filler Alloy: None

Cleaning: Clean end cap with alcohol
in ultrasonic cleaner for
15 min. Clean cladding
according to attached
procedure.

No: 19
Date: 9/22/69

Initial Current: 16 Amps

Upslope Rate: 0

Weld Current: 16 Amps

Voltage: 14 to 16

Weld Time: 14 sec

1 Rev Time: 12 sec

Down Slope Rate: 5 sec

Finish Current: 5 Amps

Stop Delay: 0

Down Slope Time: 5 sec

Fixture Speed in./
min: 4

Fixture Dial
(Ref): 35

Start Arc:
Running Start

UPPER END-CAP WELDINGPurpose

To produce high quality, reliable welds for fuel pin end closures. This is to be accomplished by the use of a carefully controlled welding procedure.

Equipment

- (a) Tube welding head and fixture (Drawing H-3-15284)
- (b) Welding power supply
- (c) Shaded welding glass No. 10 for eye protection
- (d) Stainless steel wire brush (0.006 maximum wire diameter)
- (e) Wire brushing fixture

Materials

- (a) Loaded CCTL Mark II pins
- (b) Argon 25% - Helium 75% mixed gas
- (c) Upper end caps (SK-3-15243 Rev. 7)
- (d) Tungsten 2% thoriated electrodes
- (e) Plenum springs (SK-3-15243 Rev. 7)
- (f) Plenum tube-plug assembly (SK-3-15243 Rev. 7)

Procedures

1. Set weld sequence programmer for the attached welding procedure.
2. Check programmer timing devices using a stop watch.
3. Check rotation of tube or welding heat with stop watch.
4. Check gas supply and flow.
5. End caps shall be cleaned in an ultrasonic cleaning tank with alcohol for 15 min.
6. Remove the plastic end bag from the loaded CCTL Mark II pin and insert pin into welding fixture. Open end of pin should never be placed below horizontal in such a manner that the internal components may move.

7. Insert spring in open end of pin.
8. Insert plenum tube with the plug end against the spring.
9. Fill the pin with helium just prior to inserting the end cap.
10. Insert the end cap, carefully checking the fit between the tube and end cap. Align top and bottom end cap slots according to SK-3-15243.
11. Complete weld in accordance with established welding procedure (No. 19).
12. Wire brush weld to remove oxide formed during welding if specified by fabrication engineer. Wire brushing shall be accomplished using a stainless steel wire brush where the wire diameter does not exceed 0.006 in. in diameter. Pressure on the part during brushing shall be controlled by the use of the wire brush fixture, so that no more than 0.0005-in. is removed from the OD of the tube.
13. A weld sample shall be taken after every 25 welds.
14. Completed welds shall be inspected visually, helium leak tested, and radiographed.

NOTE: Weld samples shall be a 6-in. length of cladding from the same lot as the pins being fabricated. End caps shall be selected from those being processed.

WELDING PROCEDURE

Date: 9/22/69

Project: CCTL Mark II
Upper End Caps

Process: TIG

Alloy: 316 SS

Power Source: Merrick E.S.R. 300
(USA HW522979)

Torch: HWS20 (Welding Head)

Cup: Gas Screen No. 4 Cup

Shielding Gas: He-A
Type: 75% - 25%
Volume: 60 CFH

Electrode:
Type: 2% Thoriated
Tungsten
Diam: 1/16 in.
Ext.: 0.250 in.
Shape: 30 degrees

Initial Current: 16 Amps

Upslope Rate: 0

Weld Current: 15 Amps

Voltage: 14 to 16

Weld Time: 14 sec

1 Rev Time: 12 sec

Down Slope Rate: 5 sec

Finish Current: 5 amps

Stop Delay: 0

Down Slope Time: 5 sec

Fixture Speed in./
min: 4

Fixture Dial
(Ref.): 35

Start Arc: Running Start

Filler Alloy: None

Cleaning: Clean end cap with
alcohol in ultrasonic
cleaner for 15 min.

WELD REWORKING

To remove excessive weld build-up from the outside diameter of fuel pin end closure weld.

Equipment

- (a) Rotating chuck
- (b) Micrometer
- (c) Swiss files (cut No. 2)

Materials

- (a) Completed fuel pin closure weld.

Expendables

- (a) 400 grit silicon carbide paper
- (b) Acetone
- (c) Ethyl alcohol

Limitations

1. Welds which exceed the maximum diameter of the drawing by more than 0.005 in. shall not be reworked.
2. Weld rework shall be restricted to the weld bead and will not alter the cladding OD by more than 0.0005 in.
3. Control samples shall be reworked in the same manner as the end closure welds.
4. Welds which have been reworked shall not be rewelded.
5. All reworking shall be accomplished prior to non-destructive testing. (radiography, leak check, etc.)

Procedure

1. Place fuel pin in rotating chuck.
2. Measure fuel pin cladding OD
3. Measure fuel pin weld (tube welded to end cap).
4. Apply 400 grit silicon carbide paper to weld.
5. Measure weld often to find high point of weld.

6. High point of weld may be removed by light filing.
7. Polish weld with 400 grit silicon carbide polishing paper.
8. Weld shall not exceed +0.003 of OD of tube.
9. Clean weld area using acetone and ethyl alcohol.
10. Check cladding outside diameter for minimum and maximum diameter.

FUEL PELLET LOADING

Purpose

To load reflector rods and fuel pellets that have been centerless ground, characterized, and accepted.

Equipment

- (a) Dial caliper
- (b) Triple beam balance readable to 0.1 g or equivalent
- (c) V-trough loading device
- (d) Transfer tube
- (e) Pellet seating rod (marked at 6 in. intervals)
- (f) Column length gauge
- (g) Plastic end bag

Procedure

1. Check quality assurance follower cards to ensure that fuel has been characterized and accepted, and that the lower end caps have been welded and accepted.
2. Load six 1-in. stainless steel reflector rods into cladding tube.
3. Weigh 187 to 190 g of pellets from characterized fuel batch.
4. Place 6-in. of pellets in V-trough and insert into transfer tube.
5. Load pellets into cladding tube, using pellet seating rod to ensure that pellets are in place.
6. Repeat steps 4 and 5 until all pellets which have been weighed are used.
7. Measure column length with column length gauge. If column is short, weigh and load additional pellet(s) so column length is $37 \pm 1/8$ in.

8. Record column length and weight on quality assurance follower card.
9. Load six 1-in. stainless steel reflector rods.
10. Seal end of tube by placing plastic end bag over end of tube and taping to tube to prevent contamination during storage.

HELIUM LEAK TESTING

Purpose

To nondestructively test completed fuel pins to ensure that no pins having a leak rate greater than 10^{-8} cm³/sec of helium will be accepted for irradiation.

Equipment

- (a) Helium mass spectrometer leak detector
- (b) Helium leak test fixture
- (c) Calibrated standard helium leak.

Materials

- (a) Fuel pin with both ends closed

Expendables

- (a) Liquid Nitrogen
- (b) Ethyl alcohol
- (c) Acetone

Procedure

1. Completed fuel pins shall be leak tested within three days after removal from the welding chamber.
2. Pins shall be leak tested after any rework (i.e. weld dressing) has been completed.
3. Fill cold trap with liquid nitrogen.
4. Push test valve on.
5. After five min warm up time, open inlet valve.
6. Leak detector shall be calibrated daily in accordance with operating manual.
7. Attach standard leak and check response prior to any testing.
8. Push air release valve off (vent).

9. Clean fuel rods with alcohol or acetone before inserting rod in tube.
10. Open manifold valve.
11. Insert loaded fuel pin in tube and attach tube end to leak detector.
12. Push test valve to ON position.
13. Watch output meter for leak rate. Any indication of a leak rate larger than 10^{-8} cm³/sec is cause for rejection.
14. Push air release valve to OFF position (vent).
15. Remove loaded fuel pin from tube.
16. Attach standard leak and check response.
17. Close manifold valve.
18. Push test valve ON.
19. Push air release OFF.
20. Attach leak detector in standby position.
21. Repeat Steps 7 through 20 for each fuel pin.

CCTL MARK II FABRICATION STEPS

PROFILOMETER MEASUREMENTS

1. Handle cleaned fuel pins with gloves
2. Insert fuel pin in profilometer with bottom end-cap in chuck. Make sure that fuel pin is supported along its length.
3. Turn on strip recorder (check ink supply, paper, etc.).
4. Start fuel pin movement, guiding top end cap through guide holes.
5. Stop fuel pin ~3 in. from bottom end-cap, and return carriage to initial position.
6. Reverse pin with top end in chuck.
7. Start fuel pin movement and guide bottom end until ~3 in. from end cap have been recorded.
8. Stop machine; remove and label recorded chart.
9. Follow same procedure for the 40 fuel pins to be characterized.

WIRE WRAP

1. Handle clean fuel pins and wire (0.056 in. diam., 20% CW) with gloves.
2. Weld one end of wire to one end of cap. With characterized pins, make sure that labeled end of characterized wire is welded to the top end cap. Check drawing SK-3-15243 to ensure proper orientation.
3. Insert fuel pin in wire wrap fixture.
4. Apply 8.5 ± 0.5 lb tension to wire.
5. Wrap wire around fuel pin. Check drawing SK-3-15243 to ensure proper direction of wrapping.
6. Clamp wire to pin a few in. from end cap and cut end of wire.
7. Weld wire to end cap.

ASSEMBLE STRIP LAYERS

1. Handle fuel pins and strip layers with gloves.
2. Slide wrapped pins onto lower grid plate. Keep uniform orientation of pins by noting position of wire welds.
3. Record each tube number and its position in the strip layer. Make sure that the characterized pins are in the proper location.
4. Insert attachment pins through holes in end cap and grid plate.
5. Spot-weld each pin to each end cap on both sides of strip layer.
6. Record the strip layer number and label the strip layer.

ASSEMBLE BUNDLE

1. Place lower grid frame in the proper position in the subassembly fixture.
2. Install each strip layer in order in the subassembly fixture, positioned properly in the lower grid frame. Check each strip layer number with its position in the bundle.

3. Identify one end of the lower grid frame with a 1 marked with a vibra tool. The duct identification number will be placed on the corresponding duct flat.
4. Insert the dummy locking bars in the lower grid.
5. Line up the pins and install the upper grid assembly.

ASSEMBLE SUBASSEMBLY

1. Drill pressure tap holes in duct.
2. Clean duct.
3. Characterize duct as follows:
 - a. Measure the outside "diameters" across each flat and across the corners at specified locations along the duct length.
 - b. Measure the wall thickness on each flat at each end of the duct.
 - c. Measure the bow in each flat. Use a dial indicator set up on a granite table and reference all readings to one point.
 - d. Determine twist measurements from bow data.
4. Lower duct over bundle and install lower locking bars.
5. Weld lower locking bars and upper grid to duct.
6. Slip ring flanges over duct and spot weld in proper position.
7. Remove the duct from the subassembly fixture. Steps 8 to 11 may be done in any order.
8. Align pressure top bosses (4) with the pressure tap holes and weld to the duct. Weld pressure tap pipes (4) to duct.
9. Weld top flange to the top of the duct.
10. Die penetrant test the upper and lower grid-duct welds.
11. Weld accelerometer studs (4) to the duct.

12. Weld nosepiece to bottom end of duct. Start by tack welding; then fill in a little at a time on opposite flats continually checking alignment of the nosepiece with the duct.
13. X-ray nosepiece weld.

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APPENDIX E

LOWER GRID PLATE WELD DEVELOPMENT

LOWER GRID PLATE WELD DEVELOPMENT

An electron beam welding technique was developed for fabrication of the layer spacing grid plate assembly. This technique was then used to weld the round rail to the plates. The weld parameters are listed in Table E.1.

TABLE E.1. Layer Spacing Grid Plate Weld Parameters

Welding Machine	Hamilton Standard Electron Beam Machine Model No. EBW(6)52-36-36
Beam Size	0.003 to 0.005 in. (fine spot)
Current, filament beam	1.525 amp 2.0 ma
Voltage	105 kV
Speed	30 in./min
Start	Running, full power
Overshoot	To rail extension
Atmosphere	Vacuum, 5×10^{-5} Torr
Focal Height	5.0 in.
Beam - Plate Angle	20 degree

A 0.005 in. flat was machined on the rails to allow for weld build-up and for assembly of pins onto the finished plate. Figure E.1 shows a cross section of the grid plate and the relative position of the electron beam, the 0.005-in. flat, the rail, and grid plate.

Metallographic examination of the welds was performed to verify the existence of adequate penetration in the correct position as shown in Figure E.2. A weld sample is shown in Figure E.3. These samples had 0.010 in. flats on the rails. As can be seen, the weld build-up is minimal and the lower end caps fit without any additional preparation after welding. The same was also true with an 0.005-in. flat.

FIGURE E.1. Electron Beam Weld Position

FIGURE E.2. Electron Beam Weld Cross Section, 38X

FIGURE E.3. Electron Beam Weld Sample

Weld samples were prepared for the purpose of tensile testing both the weld and the end-cap. These samples are shown in Figure E.4 after the tensile tests. The results of the test are given in Table E.2. Samples No. 1 to 3 were to test the weld strength; samples 4 to 6 were to determine the point at which the end cap slot springs open. If a force of 225 lb is exerted on each pin, the stress in each grid plate is $\sim 25,000$ psi, which is less than $1/4$ of the strength required to fracture the weld. Thus, the weld strength is sufficient for CCTL operation.

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FIGURE E.4. Tensile Test Samples

TABLE E.2. Tensile Test Results

Sample Number	Width, in.	Thickness, in.	Weld Area, in. ²	End Cap Area in. ²	Load, lb	Strength, psi
1	0.253	0.032	8.1×10^{-3}		954	118,000
2	0.253	0.032	8.1×10^{-3}		975	120,000
3	0.253	0.032	8.1×10^{-3}		888	110,000
4	0.504	0.032		0.0176	225	12,800
5	0.512	0.032		0.0176	225	12,800
6	0.511	0.032		0.0176	255	14,500

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APPENDIX F
SHIPPING FORCES

SHIPPING FORCESDESCRIPTION OF MARK II SHIPMENT

The Mark II CCTL assembly was the first full-scale prototypical FIR fuel assembly shipped with accelerometers to monitor the forces encountered during a shipment to ANL Chicago. Forces of 30 G's were recorded which were felt to be exceptionally high considering the special packaging and shipping conditions.

The Mark II subassembly was crated inside a wooden shipping container built to DOT Specification 15-B, Section 78.169. This box, in turn, was crated inside a second box with resilient Type 2 padding. Four accelerometers were mounted on the inside of the inner box, two near each end.

The shipment left Richland on February 25, 1970, by truck for Portland, Oregon. At Portland, the subassembly was loaded on a cargo plane and flown to San Francisco where it changed planes to Chicago. It was shipped by truck from Chicago to ANL on March 2, 1970. Reports of those witnessing the shipment indicate no evidence of unusual drops or rough handling.

ACCELEROMETER READINGS ON FFTF MARK II TEST

Four accelerometers were mounted within the box: two at the top end of the test assembly (Ser. H-33 @30G full scale and H-33 @50 G) and two at the bottom end of the assembly (Ser. H-32 @30G full scale and H-32 @50 G). The 30 G instruments measured loadings in the up-down, fore-aft plane; the 50 G instrument measurements were in the right-left, fore-aft plane.

Readings recorded during the shipment were:

<u>Serial</u>		<u>Most of the Readings % of Scale</u>	<u>Maximum Recorded % of Scale</u>
H-33 (30 G Scale)	up	20	45
	down	35	50
	fore-aft	12	± 2
H-33 (50 G Scale)	right-left	± 10	± 15
	fore-aft	± 5	± 5
H-32 (30 G Scale)	up	25	90
	down	40	100+
	fore-aft	± 10	± 10
H-32 (50 G Scale)	right-left	± 8	± 8
	fore-aft	± 3	± 3

The maximum up-down readings indicate that one relatively large shock loading was sustained in that direction. No box damage was noted and no immediately obvious damage to the assembly exterior was found.

BNWL-1418

APPENDIX G

DROP TEST

DROP TESTOBJECTIVE

The objective of this test was to evaluate more fully the force levels that might be encountered during shipment of a prototypical FTR assembly and to ascertain what magnitude of shock would be capable of producing a force of 30 G's on the assembly. The test consisted of a series of drop tests using a simulated packaged Mark II assembly.

SUMMARY AND CONCLUSIONS

Forces of 30 G's or greater were recorded on the assembly for free fall drops of 12 in. or higher. No significant forces were experienced in directions other than the vertical.

- Levels of 5 to 8 G's were experienced during the short truck ride to the test pad. A 2-in. drop test gave similar readings of 6 to 9 G's.
- The force levels are very sensitive to the manner in which the box hits, and how the resultant shock wave is transmitted. Some of the variability seen in the attached tables was induced by this effect. Although "flat" drops were attempted, this cannot be consistently achieved under actual conditions where one corner or edge may strike an instant before the entire assembly. This effect is further shown in the following two cases:
- In a "cornerdrop" with one end of the assembly 2 in. from the pad and the other elevated only 8 in., levels up to 27 G's were obtained; the higher forces experienced at the 2-in. end. This is very similar to the type drop that would be obtained from a forklift when one end of a box is placed on the ground and the forklift backed out, dropping the second end.

- Two test drops were made from 12 in. In one, force levels from 11 to 30 G's were obtained; in the second, 18 to 27 G's and, the high readings were at the opposite end from the first test.
- For drops of 9 in. and under, the effect of a missing support on the nosepiece end of the assembly can be seen by the slightly higher force readings, (see Table G.1)*. In general, above 9 in. the readings become similar.
- No visible damage to the box was noted after completion of all tests. The assembly was removed from the duct. No visible damage to the outer layer of fuel pins was detected. Additional details are presented in Table G.2.

DISCUSSION

Test Assembly Description

To duplicate the conditions of the Mark II CCTL assembly, the drop test assembly was made as follows.

To simulate mass and length, the Mark I subassembly was inserted and pinned in a long section of hexagonal duct. Distribution of mass along the length was simulated as closely as possible.

Both the inner and outer shipping boxes and the packing were identical to Mark II conditions except that the test boxes were made of plywood instead of wood.

Three calibrated accelerometers were located at each end of the assembly. With this arrangement, each axis at each end was monitored by two of the meters. The vertical axis was monitored at each end by one meter on the wall of the inside shipping box and another meter mounted to the fuel assembly.

* *One duct support was removed from the area normally holding the assembly nosepiece. The original support did not match the test duct and time did not permit replacement.*

TABLE G.1. CCTL Drop Test, Vertical Forces

Accel. Ident.	Location	Release Height, in.					
		2	6	9	12	15	18
Downward Forces in G's							
B	Inner Box ¹	9	10.5	21	21	27	27
C	On Element ²	9	10.5	18	21	27	30+
D	On Element	6	7.5	12	18	27+	27+
E	Inner Box	6	12.0	18	27	30+	30+
Upward Forces in G's							
B	Inner Box	0	0	12	12	19.5	19.5
C	On Element	0	0	7.5	7.5	18.0	19.5
D	On Element	6	6	6	6	12.0	12.0
E	Inner Box	0	4.5	6	12	24.0	24.0
Two Drops at 12 In.							
Downward Forces in G's				Upward Forces in G's			
		1st Test	2nd Test	1st Test	2nd Test		
B		30	21	27	12		
C		30	21	21	7.5		
D		10.5	18	10.5	6		
E		16.5	27	10.5	12		

1. Accelerometers B and C are at nosepiece end; D and E at top end.

2. Accelerometers C and D are mounted on the element; B and E on the inner box wall.

TABLE G.2 CCTL Drop Tests, Corner Drop and Controlled Drop

<u>Accel.</u>		<u>Corner Drop</u>	
		<u>Downward Forces, G's</u>	<u>Upward Forces, G's</u>
B }	2-in. Off Pad	21.0	16.5
C }		27.0	15.0
D }	8-in. Off Pad	15.0	6.0
E }		24.0	9.0
		<u>Controlled Drop and Jerk, G's</u>	<u>Truck to Site, G's</u>
B		4.5	7.5
C		4.5	7.5
D		3	6.0
E		3	4.5

The weight of the fuel assembly was 296 lb (315 for Mark II) and the total weight of the unit tested was 710 lb. The Mark II total weight was 790 lb.

Test Conditions

- Accelerometer readings were taken after:
 - Loading the assembly on a flatbed truck and transporting to test site (~2 miles).
 - A series of free-fall drop tests ranging from 2 to 18 in. Two tests were made from the 12-in. height.
 - A corner drop with one end of box elevated 2-in.; and the other end 8-in.
 - A controlled drop and quick stop to simulate various lifting devices. Tables G.3 and G.4 summarize the results of these tests. Figures G.1 through G.3. show the same data in graphical form.

FIGURE G.1. CCTL Mark II Drop Test, Vertical Acceleration, Down

FIGURE G.2. CCTL Mark II Drop Test, Vertical Acceleration, UP

FIGURE G.3. CCTL Mark II Drop Test

APPENDIX H

TEST ASSEMBLY ALIGNMENT

1881-1882

1881-1882

The necessity to control alignment of individual components of the completed test assembly and also of the completed FIR fuel assemblies is recognized. To determine the amount of misalignment possible in the CCTL Mark II test assembly, the following study was made.

A tolerance stackup analysis was made (included in this appendix) of the test assembly components (duct, spacer ring, nosepiece, and ball seat) to determine the amount of total runout possible if all tolerances (form, size, and location) in the respective parts were exhausted. The analysis showed, for the worst case, that a total runout of 0.070 in. is possible if all component tolerances were used up. These TIR stackups are broken down as follows:

Case I

Lower ring displacement caused by cocking of nosepiece (See Figures H.1 through H.7 of tolerance stackup analysis)

Cocking displacement	0.026 in. = 0.052 in. TIR*
Ring to duct mismatch	<u>0.009 in.</u> = <u>0.018 in. TIR</u>
Total Displacement	0.035 in. = 0.070 in. TIR

Upper ring displacement due to cocking of nosepiece (See Figures H.1 through H.7 of tolerance stackup analysis).

Cocking displacement	0.014 in. = 0.028 in. TIR
Ring to duct mismatch	<u>0.009 in.</u> = <u>0.018 in. TIR</u>
Total Displacement	0.023 in. = 0.046 in. TIR

* *Total Indicator Reading*

Case II

Lower ring displacement caused by duct bow (See Figure H.2 of tolerance stackup analysis).

Total Displacement = 0.023 in. = 0.046 in. TIR

Upper ring displacement due to duct bow (See Figure H.2 of tolerance stackup analysis).

Total Displacement = 0.014 in. = 0.028 in. TIR

Case I and Case II are not additive; therefore, the worst case is a TIR of 0.070 in. for the lower spacer ring.

A similar analysis for the as designed FTR fuel assembly is being performed. Also allowable clearances in the FTR core are being analyzed. It may be necessary to change some dimensional tolerance on individual FTR fuel assembly components. As an added measure, special fixturing has been designed and fabricated to provide more positive control of alignment of components of completed fuel assemblies. This fixturing will be initially used during the assembly of the spare duct assembly to be used in the CCTL for instrumentation testing in the event the CCTL Mark II test assembly is removed from the test loop for long periods of time.

USING SMALL DIAM (SEC A-A SK-3-14696) OF NOSE PIECE
 AND LARGE BORE (SK-3-14696) OF BALL SEAT
 MAXIMUM C_L OFFSET = 0.005 in.

TOTAL DISPLACEMENT FOR NOSEPIECE = 0.035 in.

FIGURE H.1. Cocking of Nosepiece

FIGURE H.2. Upper and Lower Ring Displacement Caused by Allowable Duct Bowing and Nosepiece Cocking

FIGURE H.3. Maximum Ring Displacement

$\frac{4.655}{4.650}$	$\frac{0.005 \text{ in.}}{0.004 \text{ in.}}$
0.005 MAX HEX DISPLACEMENT	0.009 in. MAX DISPLACEMENT
$\frac{6.538 \text{ in.}}{-3.267 \text{ in.}}$	0.025 in. MAX DUCT DISPL.
$\frac{3.271 \text{ in.}}{-3.267 \text{ in.}}$	0.009 in. MAX SPACER DISPL.
0.004 MAX DIAMETER DISPLACEMENT	0.034 MAX DISPLACEMENT

FIGURE H.4. Ring Displacement Caused by Dimensional Tolerances

$$\begin{array}{r}
 4.359 \text{ in.} \\
 -2.172 \text{ in.} \\
 \hline
 2.187 \text{ in.} \\
 -2.172 \text{ in.} \\
 \hline
 0.015 \text{ in.}
 \end{array}$$

MAX DISPLACEMENT
INSIDE

$$\begin{array}{r}
 2.172 \text{ in.} \\
 +0.140 \text{ in.} \\
 \hline
 2.312
 \end{array}$$

$$\begin{array}{r}
 4.649 \text{ in.} \\
 -2.312 \text{ in.} \\
 \hline
 2.337 \text{ in.} \\
 -2.312 \text{ in.} \\
 \hline
 0.025 \text{ in.}
 \end{array}$$

MAX OUTSIDE
DISPLACEMENT

4.659 in. MAX OUTSIDE DIMENSION (WILL NOT FIT)

FIGURE H.5. Duct Dimensions and Tolerances

FIGURE H.6. Top Flange Perpendicularity Tolerance

FIGURE H.7. Duct End Perpendicularity Tolerance

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