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AEC Research and
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UC-81, Reactors - Power
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**SM-2 SINGLE ELEMENT
FINAL TEST REPORT**

ALCO PRODUCTS, INC.

NUCLEAR POWER ENGINEERING DEPARTMENT

P. O. BOX 414, SCHENECTADY 1, N. Y.

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**SM-2 SINGLE ELEMENT
FINAL TEST REPORT**

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Issued: October 28, 1960

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New York Operations Office

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ABSTRACT

Tests were conducted on an SM-2 control rod assembly and stationary element to determine channel-to-channel coolant flow distribution and static pressure drops across both the control rod assembly and stationary element, and to select proper top and bottom core support configurations necessary to bring stationary element channel-to-channel flow distribution within prescribed limits of $\pm 6\%$ of element average. Results showed control rod channel-to-channel flow distribution was $+7.0\%$ and -7.4% of element average, within required $\pm 12\%$. Pressure drop across the control rod assembly was measured as 29.0 ft of water (80°F) at design flow rate of 331 gpm. First pass stationary element pressure drop was measured as 17.1 ft of water (80°F) at a flow rate of 272 gpm; flow distribution was $+7.7\%$ and -10.7% of element average, not within prescribed $\pm 6\%$, but since actual element flow was much higher than required by thermal design, the flow profile was felt acceptable. Second pass stationary element pressure drop was measured as 28.8 ft of water (80°F) at a flow rate of 346 gpm; channel-to-channel flow distribution was $+4.3\%$ and -4.5% of average element velocity at a flow rate of 346 gpm, within prescribed limits of $\pm 6.0\%$.

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1.0 SUMMARY

The report gives results of single element low pressure flow testing conducted on an SM-2 control rod assembly and stationary fuel element as part of SM-2 Core and Vessel Task 6.0. Objectives of testing were:

1. To determine channel-to-channel coolant flow distribution for both the control rod and stationary element.
2. To determine static pressure drops across both the control rod and stationary element. First pass pressure drop across the stationary element was required to be as low as possible while second pass pressure drop was to match that of the control rod assembly.
3. To determine proper top and bottom core support configurations necessary to bring stationary element channel-to-channel flow distribution within prescribed limits of $\pm 6\%$ of element average.

1.1 CONTROL ROD ASSEMBLY TESTING

Control rod pressure drop was experimentally measured as 29.0 ft of water (80°F) at the design flow rate of 331 gpm. Flow velocity distribution for the control rod was within prescribed limits of $\pm 12\%$ of average, actual results being $+7.0\%$ and -7.4% of average. Individual control rod component pressure drops are tabulated in Section 3.4.7.

1.2 STATIONARY ELEMENT TESTING

Bottom and top core support configurations experimentally selected for the first pass stationary element were Styles 9c Rev. A (Fig. 4-19) and 9a (Fig. 4-15) respectively. For second pass stationary elements, the bottom and top core support configurations selected were Styles 13 Rev. A (Fig. 4-32) and 9b Rev. A (Fig. 4-21) respectively. Overall stationary element pressure drop for first pass was 17.1 ft of water (80°F) at a flow-rate of 272 gpm while second pass stationary element pressure drop was measured as 28.8 ft. of water (80°F) at a flow rate of 320 gpm. The selected core support design met the objectives of low first pass pressure drop, and a second pass pressure drop which matched that of the control rod assembly.

The first pass combination of top and bottom core support configurations resulted in channel-to-channel flow distribution with $+7.7\%$ and -10.7% of average channel velocity. This was not within the target limits of $\pm 6\%$; but since first pass channel flow rate is actually 20% higher than required by thermal design, the above limits were believed acceptable for first pass flow.

Second pass channel flow distribution was +4.3% and -4.5% of average channel velocity, which was within $\pm 6\%$ imposed by design requirements.

The selected core support design gave optimum flow distribution for both first and second pass sections of the core, with the required minimum first pass pressure drop across stationary elements and second pass pressure drop matching that of the control rod assembly.

2.0 INTRODUCTION

Single element low pressure flow testing was performed in the Alco General Engineering Laboratory at Schenectady, New York, as part of SM-2 Core and Vessel Task 6.0 - Core Hydraulic Analysis and Test. Testing was done on a loop previously used in similar testing for the SM-1A reactor.

Objectives of the test program were to experimentally determine both flow distribution and pressure drop data of an SM-2 control rod assembly and stationary element. The program was also to result in experimental selection of a bottom and top core support configuration which would give optimum flow distribution for both first and second pass sections of the core.

The target limits for both first and second pass channel-to-channel flow distribution were $\pm 6\%$ of element average. First pass flow distribution requirements were not as stringent as second pass due to excess total flow. Good channel-to-channel flow distribution was necessary because maldistribution would present a serious problem to core thermal design by introducing channel hot spots. Average or better than average flow in the lattice region was required because high flux peaks were expected to occur in this region.

Experimentally determined pressure drop data would be used in selection of a top and bottom core support configuration. First pass stationary element pressure drop was to be minimum while second pass stationary element pressure drop had to match that of the control rod assembly.

Many different combinations of bottom and top core support configurations were tested before selecting the combination which gave both the required pressure drop and flow distribution for first and second pass regions of the core.

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3.0 CONTROL ROD ASSEMBLY TESTING

3.1 PURPOSE OF TESTS

The purpose of single element flow testing of the control rod assembly was:

1. To determine experimentally the pressure drops through the complete SM-2 control rod assembly and its various components.
2. To determine the channel-to-channel flow distribution within the fuel element of this control rod.
3. To recommend and test any design modifications necessary to bring flow distribution within the prescribed limits of deviation from average.

3.2 DESCRIPTION OF TEST RIG AND INSTRUMENTATION

The test rig used for this testing consisted of a straight section of pipe into which the control rod assembly was inserted. Large plenum chambers at each end of the straight section served as flow straighteners and provided regions for static pressure measurements (overall control rod pressure drop). The space between the control rod and pipe was sealed to force total loop flow through the rod, simplifying total flow measurement. The test rig is shown in Fig. 3-1 and 3-2. Various control rod components and sub-assemblies and the instrumented control rod itself are shown in Fig. 3-3 through 3-11.

Instrumentation consisted of both static and total pressure probes. During initial testing, a fuel element containing removable instrumented plates was used but it was found that, due to handling difficulties and pressure gradients, these plates were being distorted during testing and causing erroneous velocity measurements. This fuel element was then replaced by a standard SM-2 control rod element having all plates welded. Instrumentation of the fuel element was then achieved by total and static pressure probes mounted in rakes and located at the exit of the fuel element, with both a total and static pressure probe located in each channel. Individual static pressure probes were also located so that static pressure differentials could be obtained across the following:

1. Inlet yoke
2. Fuel element and absorber
3. Cap
4. Exit
5. Plenum to plenum (overall) - see Fig. 3-9.

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Fig. 3-1 Dwg. C9-50-1244, Control Rod Single Element Rig

NOTE: DWG. REFS. ARE ALCO GEN'L MECH. LAB. ATOMIC SECTION

BREAK SHARP EDGES
REMOVE ALL BURRS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES OR FINISHED
FRACTIONAL DIMENSIONS
TO BE ±

✓ FINISH AS INDICATED
IN SPECIFICATIONS.
/1 MACHINE FINISH - ROUGH
/10 FLAME CUT OR SAW

DATE	REV.	REVISION RECORD	AUTH.	DR.	CHK.

PART NO. C9-50-1244

6	2	1078	SUPPORT FLANGE
5	2	1073	FLANGE
4	1	1077	EXTENSION PIPE
3	1	1068	PIPE
2	1	1070	CHAMBER
1	2	1072	PLENUM CHAMBER
P. QUAN. NO. REQ'D			Dwg. N

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NUCLEAR POWER ENGINEERING DEPT.		SCHENECTADY, N. Y., U. S. A.	
SCALE: 1" = 1'-0"	REV.	DR.	R. L. 7-13-60
MATERIAL SPEC.	TR.	CHK.	7-21-60
		APPR.	9-6-60
		NET.	9-6-60

NAME SINGLE ELEMENT RIG
CONTROL ROD (LAB.) SM-2
PART NO. C9-50-1244

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Fig. 3-2 SM-2 Control Rod Test Section

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Fig. 3-3 Dwg. C9-50-1107, SM-2 Control Rod Yoke Assembly

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Fig. 3-4 Dwg. C9-13-1029, SM-2 Control Rod Cap Assembly

SECTION A-A

BREAK SHARP EDGES
REMOVE ALL BURRS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES.
TOLERANCES ON FINISHED
FRACTIONAL DIMENSIONS
TO BE ± .010

✓ FINISH AS INDICATED
IN MICROINCHES.
/1 MACHINE FINISH - ROUGH
/10 FLAME CUT OR SAW

DATE	LET.	REVISION RECORD	AUTH.	DR.	CHK.
3-22-60	A	THIS DWG. REDRAWN AND REVISED TO DETAIL P.C. NO. 486	ECO-0204RM	AK	
4-7-60	B	REVISED QTY WAS 1 (2159)	AK	BP	AK

PART NO.
C-9-13-1029

QTY	PC. NO.	DRAWING NO. OR MATERIAL	DESCRIPTION
7	4	A-9-13-2142	(UPPER) LUG
6	1	B-9-13-2139	(UPPER) SLEEVE
5	1	A-9-13-2126	(UPPER) SPRING
4	1	B-9-13-2141	BODY
3	4	A-9-13-2146	(SPECIAL) SCREW
2	1	A-9-13-2127	LOWER SPRING
1	1	B-9-13-2140	LOWER SLEEVE

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SCHENECTADY, N. Y., U. S. A.

SCALE FULL	REF. R9-14-1005	DR. M. SWIDERSKY	6-16-59
MATERIAL SPEC.		TR. R. W. H. H.	3-22-60
		CHK.	
		APPR. J. J. C.	1-4-60
		APPR.	
		MET. R. W. H. H.	1-7-60

NAME
ASS'Y.-CAP CONTROL ROD

PART NO.
C9-13-1029

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DATE	LET	REVISION RECORD	AUTH.	DR.	CHK.
6-8-59	A	FIN. ADDED			WJL
		NOTES ADDED			
		23 5/16 DIM. WAS REF. DIM.			
8-12-59	B	ADDED NOTE: WELD TO BE AT PIN WELD			
		1/2 TYP. WELD AT			
		CORNER REMOVED			
		1/8 DIM. AT CORNER			
		WELD REMOVED			
		SHAPE & DIM. CORNER WELD CHANGED			
		45° ANGLE AT CORNER			
		WELD REMOVED			
		25° WAS 23 5/16			
		CIRCLE AROUND	CCS		
		WELD ADDED	DPD	RM	mac

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		SCHENECTADY, N. Y., U. S. A.	
SCALE	FULL	DR.	Standard 8-58
MATERIAL SPEC.		TR.	1/2/59
		CHK.	1/2/59
		APPR.	1/2/59
		APPR.	
		MET.	REC. 1/2/59
NAME		ABSORBER	
PART NO.		D9-13-2094	

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DATE	LET.	REVISION RECORD	AUTH.	DR.	CR.
11-16-57	A	ENLARGED MEN OF SIDE PLATE ADDED			
		SECTION AT C ALTERED	JTC	HL	
12-4-57	B	DIMENSIONS ADDED FOR HANDLE.			
		CUTOUT REMOVED.	JTC	HP	

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Fig. 3-7 Dwg. B9-50-2285, SM-2 Control Rod Rake

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Fig. 3-8 Dwg. C9-13-2137, SM-2 Control Rod Tube

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Fig. 3-9 Dwg. AEL-485, Instrumented SM-2 Control Rod Assembly

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Fig. 3-10 SM-2 Control Rod - As Instrumented (Exploded View)

Fig. 3-11 SM-2 Control Rod - As Instrumented (Assembled View)

Pairs of velocity probes were also located in the cap and absorber (see Fig. 3-9). All probes were connected to a bank of U-tube manometers for indication purposes.

3.3 TEST PROCEDURE

The test consisted of varying flow rate through the control rod assembly while recording the following data at each flow rate:

1. Total loop flow-gpm
2. Water temperature - °F
3. Velocity pressure - in. Hg
 - a. In each channel
 - b. In absorber
 - c. In cap
4. Static pressure differentials - in. Hg
 - a. Across inlet yoke
 - b. Across fuel element and absorber
 - c. Across cap
 - d. At exit
 - e. Overall

Flow rates for this test were 250, 300, 350, and 400 gpm. A minimum of three comparable runs were taken during each test.

3.4 TEST RESULTS

Control rod testing can essentially be described in seven different steps. Each progressive step is described in detail below.

3.4.1 Test with Control Rod Assembly

The control rod as originally designed (see Fig. 3-12) gave outer channel flow deficiency greater than 20% at the design flow rate of 331 gpm when tested. Static pressure drop at this flow rate was 31.5 ft of water at 80°F.

3.4.2 Test with First Modification

To force more flow to the outer channels, the semicircular (radius = 1 in.) cutouts in the front of the two long fuel plates were closed with inserts.

This raised the velocity in the outer channels slightly and lowered the center channel velocity. No measurable change in static pressure drop from the as-designed condition was observed.

3.4.3 Test with Absorber Removed

The next progressive step in the test program was to determine the effect of the absorber section on outer channel flow of the fuel element. To accomplish this, a test was run with the absorber section removed.

The absorber removal resulted in raising the outer channel velocity to approximately average element velocity.

At this stage of the test program, average channel velocity was not a true average of all element channels since not every channel was instrumented. Before the next test was run, new instrumentation was installed which featured velocity measuring probes in each of the element flow channels. A more complete picture of the actual flow pattern could then be obtained.

3.4.4 Retest with First Modification

The first test using the new instrumentation was made on the control rod as modified for previous tests (see Sec. 3.4.2). Channel flow distribution during this test is shown graphically in Fig. 3-13. Maximum variation from average during this test was +8% and -13.5% at a flow rate of 350 gpm. Since thermal design calculations were based on a maximum control rod flow deviation of +12% including actual reactor vessel plenum chamber effects not reproducible in this test, it was apparent that the results obtained in this test were not satisfactory.

3.4.5 Test with Yoke Modification

Since the previous test indicated that the outer channels were receiving insufficient flow (see Fig. 3-13), the next progressive step was to try to improve this outer channel flow deficiency.

To improve flow, deflectors or turning vanes were installed in the yoke section of the control rod (see Fig. 3-14). Channel flow distribution for this test is shown graphically in Fig. 3-15. Comparing the results with the previous test, the improvement in outer channel flow was considerable. The maximum deviation from average was +7.8% and -8.1% at 350 gpm, exclusive of channels O and P which were felt to be questionable.

Inspection of the fuel element after testing revealed that the fuel plate between the two questionable channels (O and P) had actually jumped out of the mating side plate groove. This fuel plate was one of the seven remov-

able plates which had to be filed to a slightly undersized width in order to be easily removable. It was felt that this was the cause of the questionable flow readings obtained above; so, a retest was initiated.

3.4.6 Retest with Fully-Welded Fuel Element

The test element described above (Sec. 3.4.5) was replaced by a fully welded element to confirm that the abnormal flow distribution was due to the test element itself. Results of this test are shown in Fig. 3-16. Distribution was +7.0% and -7.4% from the average. A complete tabulation of data obtained from this test is given in Table 3-1.

TABLE 3-1
VELOCITY FLOW DISTRIBUTION RESULTS FOR FINAL SM-2
CONTROL ROD ASSEMBLY TEST

Channel Identification	Nominal Flow Rate - gpm			
	250	300	350	400
A	16.6	19.8	23.2	26.5
B $\nearrow$	16.2 $\nearrow$	19.1 $\nearrow$	22.5 $\nearrow$	24.6 $\nearrow$
C	17.5	20.6	24.2	27.5
D	18.0	21.4	25.1	28.5
E	16.3	19.3	22.6	24.7
F	17.6	20.9	24.6	27.9
G	17.7	21.0	24.6	28.0
H	17.5	20.8	24.3	27.3
I				
J	18.4	21.8	25.7	29.0
K	17.3	20.6	24.2	27.5
L	17.5	20.7	24.3	27.7
M	17.55	20.8	24.3	27.7
N	18.5*	22.2*	26.0*	29.5*
O	17.6	21.0	24.3	27.75
P	17.2	20.2	23.7	27.0
Q	18.0	21.5	25.3	29.4
Average	17.5	20.7	24.3	27.5

* = High +7.0%

$\nearrow$ = Low -7.4%

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Fig. 3-12 Dwg. AEL-445, Control Rod - Original Pre-Test Design

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Fig. 3-13 Graphic Profile of Channel to Channel Velocity Distribution
For SM-2 Control Rod

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DATE	BY	REVISION	RECORD	WORK	DATE
1-1-60	A	DESIGNED	RECORD	WORK	1-1-60
1-1-60	A	DESIGNED	RECORD	WORK	1-1-60
1-1-60	A	DESIGNED	RECORD	WORK	1-1-60
1-1-60	A	DESIGNED	RECORD	WORK	1-1-60
1-1-60	A	DESIGNED	RECORD	WORK	1-1-60
1-1-60	A	DESIGNED	RECORD	WORK	1-1-60
1-1-60	A	DESIGNED	RECORD	WORK	1-1-60
1-1-60	A	DESIGNED	RECORD	WORK	1-1-60
1-1-60	A	DESIGNED	RECORD	WORK	1-1-60
1-1-60	A	DESIGNED	RECORD	WORK	1-1-60

NO.	DESCRIPTION	DATE
1	CH-10-1005	1-1-60
2	CH-10-1005	1-1-60
3	CH-10-1005	1-1-60
4	CH-10-1005	1-1-60
5	CH-10-1005	1-1-60
6	CH-10-1005	1-1-60
7	CH-10-1005	1-1-60
8	CH-10-1005	1-1-60
9	CH-10-1005	1-1-60
10	CH-10-1005	1-1-60

Fig. 3-14 Dwg. R-9-14-1005, Control Rod (With Yoke Modification) - Final Design

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Fig. 3-15 Graphic Profile of Channel to Channel Velocity Distribution for SM-2 Control Rod

FLOW DISTRIBUTION SM-2 CONTROL ROD FUEL ELEMENT WITH ENTRANCE DEFLECTOR, FULLY WELDED ELEMENT TOTAL ELEMENT FLOW - 350 GRM.

Fig. 3-16 Graphic Profile of Channel to Channel Velocity Distribution for SM-2 Control Rod with Entrance Deflectors and Fully Welded Element - Final Test

Testing to achieve satisfactory flow distribution ended when the results of the above test were obtained. It was felt that the flow distribution shown in Fig. 3-16 is fully adequate to meet SM-2 design requirements. This can be substantiated by two observations:

- a. In Fig. 3-15 and 3-16, channels to the right side of the figure have higher flow rates than corresponding channels to the left. This phenomenon has been noticed in previous tests performed in the same test section and is thought to be caused by a maldistribution of flow entering the test section. Therefore, since the control rod is symmetrical about the center channel, if flow through channels B and P and D and N are averaged, maximum deviation from element average becomes $\pm 5.0\%$.
- b. Outer channels (A and Q), where flux peaks occur, receive essentially average element flow rates (see Fig. 3-15 and 3-16). This is a considerable improvement over the condition shown in Fig. 3-13 where channel A was 13.5% below average.

3.4.7 Pressure Drop Testing

Static pressure losses through the various components were measured during each of the above flow distribution tests. This was done to evaluate the effect of design changes on pressure drop even though the readings were known to be in error because of the heavy concentration of velocity probes and their leads.

For the final test of the program, the velocity instrumentation was removed from the fuel element to obtain accurate pressure drop data.

Results of the above described test are shown graphically in Fig. 3-17 through 3-21. Based on these curves the following are the experimental values of static pressure drop at a rod flow of 331 gpm and 80°F.

Overall pressure drop (plenum to plenum)	= 29.0 ft H ₂ O
Pressure drop across inlet yoke	= 8.4 ft H ₂ O
Pressure drop across fuel element and absorber	= 12.3 ft H ₂ O
Pressure drop through cap (up to discharge plane)	= 10.0 ft H ₂ O
Exit static pressure regain	= -1.7 ft H ₂ O*

- * Negative pressure loss indicates a static pressure regain as flow expands into the exit plenum chamber.

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Fig. 3-17 Static Pressure Drop Across Control Rod Cap Vs. Flow

Fig. 3-18 Static Pressure Drop Across Control Rod Fuel Element
And Absorber Vs. Flow

Fig. 3-19 Static Pressure Drop Across SM-2 Control Rod Assembly Vs. Flow

Fig. 3-20 Static Pressure Drop Across Control Rod Inlet
Yoke Vs. Flow

Fig. 3-21 Static Pressure Regain at Control Rod Cap Exit
Vs. Flow

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4.0 STATIONARY FUEL ELEMENT TESTING IN SINGLE ELEMENT TEST RIG

4.1 PURPOSE OF TESTS

Single element flow testing of stationary fuel elements had the following basic objectives:

- a. Experimentally determine the coolant flow distribution within the element for various core support designs. Distribution tolerance for the SM-2 was set at $\pm 6\%$ of element average.
- b. Experimentally determine static pressure drops across the stationary element for various core support designs. The objective of first pass design was minimum pressure drop. Second pass pressure drop had to match control rod pressure drop of 29 ft H₂O at 331 gpm and 80°F.

4.2 DESCRIPTION OF TEST RIG AND INSTRUMENTATION

The test rig used to perform this testing is shown in Fig. 4-1 and 4-2. The four adjustable by-pass lines on this rig are used to simulate the sharing of flow feed holes by adjacent stationary elements. The stationary element itself is shown in Fig. 4-3 through 4-5. After the test program was begun, a flow adjuster, shown in Fig. 4-6, was added in an effort to correct maldistribution of flow entering the test section and to give a more direct measure of static pressure in this region.

Unlike control rod testing which had no lattice flow, a lattice box was added which simulated lattice flow in both the active and inactive lattices of the stationary element. The function of the inlet and exit plugs used in each test was to provide a flow hole pattern which represented a small section of both top and bottom core support configurations.

4.2.1 Instrumentation for Initial Tests

Instrumentation consisted of static, total and velocity head probes. Static probes were located at the following points during initial testing:

1. S₁ - in entrance plenum chamber
2. S₂ - 3/4 in. from inlet plate in lattice "X" *
3. S₃ - 3/4 in. from inlet plate within element
4. S₄ - 3/4 in. from inlet plate in lattice "Y" *

* Lattices "X" and "Y" refer to flow passages adjacent to the two outer fuel plates of the element.

5. S₅ - 1/4 in. from exit plate in lattice "X"
6. S₆ - 1/4 in. from exit plate within element
7. S₇ - 1/4 in. from exit plate in lattice "Y"
8. S₈ - in outlet plenum chamber

Total pressure probes were located at the following points during initial testing:

1. T₁ - at inlet plate
2. T₂ - at inlet plate, inside element adjacent to T₁
3. T₃ - at inlet plate inside element adjacent to T₄
4. T₄ - at inlet plate outside of lattice "X"
5. T₅ - at center of element in same plane as T₁ and T₄

Velocity probes were located in a plane near the exit of the plate bundle.

4.2.2 Instrumentation for Remainder of Testing

After the fourth test was run, a change was made in the instrumentation which was used throughout all remaining tests.

Static pressure probes were now located at the following points:

1. S₁ - inlet plenum chamber
2. S₂ - inlet - flow adjuster
3. S₃ - inlet - fuel element
4. S₄ - outlet - fuel element
5. S₅ - outlet - 5 in. tube
6. S₆ - outlet plenum chamber

The total pressure probes were replaced by two pitot tubes: one adjacent to the "X" lattice and one adjacent to the "Y" lattice which are considered active lattice passages. Velocity probes were still located in a plane near the exit of the plate bundle. All probes were connected to a bank of U-tube

manometers for indication purposes.

The above mentioned instrumentation was retained throughout the remainder of the test program.

4.3 TEST PROCEDURE

Testing consisted of varying the flow rate through the stationary element while recording the following data at each flow rate:

- A. Total loop flow - gpm
- B. Water temperature - °F
- C. Velocity pressure head in each channel - in. Hg
- D. Static pressure differentials - in. Hg

1. During initial testing (1st four tests)

a. $S_1 - S_2$	e. $S_3 - S_4$
b. $S_3 - S_6$	f. $S_6 - S_5$
c. $S_1 - S_3$	g. $S_6 - S_7$
d. $S_3 - S_2$	h. $S_6 - S_8$

See Section 4.2.1 for identification of above probes.

2. For remainder of test program

- a. $S_1 - S_6$
- b. $S_2 - S_5$
- c. $S_3 - S_4$
- d. $S_1 - S_2$
- e. $S_5 - S_6$

See Section 4.2.2 for identification of above probes.

- E. Total Pressures - in. Hg (see Section 4.2.1 and 4.2.2 for identification and location).

Flow rates for this test were 200, 250, 300, 350, and 400 gpm. A minimum of three comparable runs were taken during each test.

Before running each test, both test loop and manometers were purged of air to insure correct readings. The loop was purged of air by opening bleed-off valves at various points on the loop until a solid stream of water was running out. These valves were then closed. The manometers were purged of air by opening the valve on one leg of the monometer and forcing the column of mercury to full height in the adjacent leg. This procedure was also followed for purging the other leg of the monometer.

4.4 TEST RESULTS

The entire stationary element test program consisted of eighteen different tests which were performed with various styles and combinations of inlet and exit core configurations. A tabulation of these tests is shown below and a complete description of each test will follow.

TABLE 4-1
FINAL TEST RESULTS FOR STATIONARY ELEMENT TESTING

Test No.	Pass	Core Configuration Style		Flow Distribution Results	h Ft H ₂ O at 350 gpm nom.	Modification - if any
		Inlet	Exit			
1	1st	46	46	+9.9%, -1.6% Lattices: -21% -40%		
2	1st	6	6	+3%, -5.5% Lattices: 5-10% low	19.7	
3	1st	9	6	+9%, -6.5% Low lattice flow	17.9	Added new flow adjuster assem. for this test. See Fig. 4-6
4	2nd	9	8b	Good lattice flow	41.4	New fully welded element used
5	1st	9	9a	+12%, -14.4% Lattices above avg.	18.5	Used fully welded element but went to 23" outer fuel plates; changed instrumentation as described in Sec. 4.2.2; also added end fix's.
6	1st	9	9a	+10.2%, -13.2%	18.1	Modified end fixtures
7	1st	9c	9a	+12.3%, -13.9%	21.6	
8	2nd	9c	9b	+13.2%, -15.4% Good lattice flow	34	
9	1st	9c	9a	+15.8%, -10.1% Good lattice flow	23.5	Moved end fixture struts from over 3rd to over 5th plate of element
10	1st	9c Rev. A	9a	+7%, -9.6% Good lattice flow	24.6	Rotated inlet plug 90°
11	1st	9c Rev. A	9a	+7.7%, -10.7% Good lattice flow	22.5	Inlet plug back in normal position with continuous pads added along side plate
12	1st	12a	9a	+6%, -8.4% "X" lattice 6% below average	22.9	Rotated plug 90°
13	1st	9c Rev. A Modified	9a	+9.3%, -14.4%	21.7	Made 4 breakout holes in plug
14	2nd	9c Rev. A Modified	9b	+10%, -8.2%		
15	2nd	13	9b	+5.8%, -8.2%	31.6	
16	2nd	13 Rev. A	9b	+5.01%, -9%	31.1	
17	2nd	13 Rev. A	9b	+5.02%, -8.6%	31.1	Exit plug rotated 180° to check instrumentation
*18	2nd	13a Rev. A	9b Rev. A	+4.3%, -4.5%	28.8	Three holes in exit plug opened up to reduce overall pressure drop

* Final 2nd pass test.

✱ Final 1st pass test.

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Fig. 4-1 Dwg. AES-345, Single Element Flow Test Rig Assembly

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Fig. 4-2 Single Element Flow Test Rig Assembly

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Fig. 4-3 Dwg. R9-13-1017, SM-2 Stationary Fuel Element

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UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES.
TOLERANCES ON FINISHED
FRACTIONAL DIMENSIONS
TO BE ± _____

✓ FINISH AS INDICATED
IN MICROINCHES.

(f₁) MACHINE FINISH - ROUGH

(f₁₀) FLAME CUT OR SAW

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Fig. 4-6 Dwg. C9-50-1086, Flow Adjuster Assembly

DATE	REV.	REVISION	RECORDED	AUTH.	DR.	CHK.

PART NO.
C9-50-1086

QTY	PART NO.	CODE	REV.	DATE
3	1	CARBON STL	FLOW ADJUSTER	
2	1	CARBON STL	5" O.D. X 2 1/4" X 1/8" WALL	
1	1	CARBON STL	RING 6 1/2" O.D. X 5 1/2" I.D. X 1/8" THK	
PC	NO	QTY	DATE	REV.

ALCO PRODUCTS, INC.
NUCLEAR POWER ENGINEERING DEPT.
SCHENECTADY, N. Y., U. S. A.

DESIGN	FULL	REV.	DATE	DR.	CHK.	APPR.	DATE

NAME
FLOW ADJUSTER ASSY
(SINGLE ELEMENT FLOW TEST RIG SM-2)

PART NO.
C9-50-1086

BREAK SHARP EDGES
REMOVE ALL BURRS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON FINISHED
FRACTIONAL DIMENSIONS
TO BE ± 1/16

- ✓ FINISH AS INDICATED
ON DIMENSIONS
- (1) MACHINE FINISH - BOUN
- (10) FLAME CUT OR SAW

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Fig. 4-7 DWG. AES-343, Style 46 - Support Plug - 1st Pass

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4.4.1 Test #1 Style 46 Inlet, Style 46 Exit (1st Pass)

For the first test, a first pass element position at the corner of the core was selected because this position represents the most difficult location for providing adequate feed holes. Style "46" (combined features of styles 4 and 6) was the configuration used for both top and bottom core support plates in this test (see Fig. 4-7).

Results of this test at 350 gpm nominal flow rate are plotted in Fig. 4-8. Extremes in the variation of channel velocities were from +9.9% to -1.6% of average velocity. However, the maximum deviations from average velocity in the two lattices were -21% and -40% in the "X" and "Y" lattice respectively.

Static pressure differentials were measured during this test but proved to be inconclusive since the component pressure drops did not match the overall measured pressure drop.

4.4.2 Test #2 - Style 6 Inlet, Style 6 Outlet (1st Pass)

For this test, a style 6 grid type core support configuration was used for both top and bottom core plates (see Fig. 4-9). This design was tested because it was thought to have the best possible chance of meeting the required flow distribution. Test results, plotted in Fig. 4-10, show the lattice flow to be approximately 5 to 10% below element average. Flow distribution within the element was between +3% and -5.5% of average at a nominal flow rate of 350 gpm.

Overall pressure drop at 350 gpm nominal was 19.7 ft of water.

4.4.3 Test #3 - Style 9 Inlet, Style 6 Outlet (1st Pass)

A modification was made to the test rig prior to the running of this test. The modification consisted of adding a flow adjuster (see Fig. 4-6) at the inlet plenum chamber in an attempt to provide more accurate pressure drop information because the original design caused a contraction pressure loss to be included in the overall drop which was not representative of reactor conditions.

This combination of top and bottom core support plates (see Fig. 4-11 and 4-9) was tested to evaluate the performance of the bottom plate with the least possible influence by the top plate. Velocity distribution was within +9% and -6.5% of average at a nominal flow rate of 350 gpm. Velocities are shown plotted in Fig. 4-12. Overall pressure drop at a nominal flowrate of 350 gpm was 17.9 ft water (80°F).

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Fig. 4-8 Stationary Element Flow Distribution (Style 46 Inlet And Style 46 Exit) - 1st Pass

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Fig. 4-9 Dwg. AES-375, Style 6, Support Plug - 1st Pass

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STATIONARY ELEMENT FLOW DISTRIBUTION

BOTTOM CORE SUPPORT PLATE: AEL-393 (STYLE 6)

TOP CORE SUPPORT PLATE: AEL-393 (STYLE 6)

NOMINAL ELEMENT FLOW: 350 g.p.m.

Fig. 4-10 Stationary Element Flow Distribution (Style 6 Inlet and Style 6 Exit) - 1st Pass

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Fig. 4-11 Dwg. AES-381, Style 9 - Inlet Support Plug - 1st Pass

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Fig. 4-12 Stationary Element Flow Distribution (Style 9 Inlet
And Style 6 Exit) - 1st Pass

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Inspection of the test element and instrumentation after disassembly of the rig revealed that the lattice passage had become distorted due to numerous assemblies and disassemblies. Consequently, lattice flow measurements were below true values. A new element and instrumentation were used for the next test. The new instrument supports provided more accurate positioning of the velocity and static pressure probes, and control of lattice passage width.

4.4.4 Test #4 - Style 9 Inlet, Style 8b Outlet (2nd Pass)

The next combination of top and bottom core configuration tested was style 9 inlet (Fig. 4-11) and style 8b exit (Fig. 4-13). This test was the first one run with a second pass top plate configuration (style 8b). Overall pressure drop through this combination was 41.4 ft of water at 350 gpm nominal, 26.6 ft of this occurring across the top support plate. This pressure drop was obviously excessive as it would result in the stationary elements having a higher pressure drop than the control rods at rated flow.

In flow distribution, lattice flow was noticeably better than any previous combination. A plot of channel velocity distribution at 350 gpm nominal is given in Fig. 4-14. The extremely high pressure drop across the top plate caused damage to the velocity measuring instruments. As a result no data is available for several channels.

4.4.5 Test #5 - Style 9 Inlet, Style 9a Outlet (1st Pass)

For this test, a fully welded element with 23 in. outer fuel plates and attached end fixtures was used. At this point a change was also made in the instrumentation (see Sec. 4.2.2).

The top and bottom core support plate configurations are shown in Fig. 4-11 and 4-15 respectively. Velocity distribution at 350 gpm nominal flow rate was within +12% and -14.4% of average with the two lattices showing above average velocity. Velocities are shown plotted in Fig. 4-16. The major reason for the increase in maldistribution over earlier tests was the foreshortening of the fuel element. The shortening reduced the redistribution of flow between the inlet support plate and the entrance to the plate bundle. Overall pressure drop for this combination of top and bottom core support configurations was 18.5 ft of water at a nominal flow rate of 350 gpm.

4.4.6 Test #6 - Style 9 Inlet, Style 9a Outlet (1st Pass)

Before conducting this test, a slight modification was made to the end fixture comb shown in Fig. 4-17. This modification was made in an attempt to improve upon the flow distribution observed in the previous test.

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STATIONARY ELEMENT FLOW DISTRIBUTION

BOTTOM CORE SUPPORT PLATE: AEL-523 (STYLE 9)
TOP CORE SUPPORT PLATE: AEL-526 (STYLE 8b)

NOMINAL ELEMENT FLOW: 350 g p m

(NO DATA COLLECTED FOR
CHANNELS B, G, I, L)

Fig. 4-14 Stationary Element Flow Distribution (Style 9 Inlet and Style 8b Exit) - 2nd Pass

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Fig. 4-15 Dwg. AES-399, Style 9a, Exit Support Plug - 1st Pass

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Fig. 4-16 Stationary Element Flow Distribution (Style 9 Inlet and Style 9a Exit) - 1st Pass

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Fig. 4-17 Dwg. B9-50-1118, Comb

DATE	LET.	REVISION RECORD	AUTH.	DR.	CHK.
10-19-60	A	CHAMFER ADDED	R.L. King		
		1/8" DEPTH OF SLOT WAS 7/8"	R.C. 0256	W.W. 97-	

ALCO ALCO PRODUCTS, INC. NUCLEAR POWER ENGINEERING DEPT. SCHENECTADY, N. Y., U. S. A.		SCALE 2 1/4" = 1 FT.	REP. B9-50-1117	DR. R.L.	1-13-60
		MATERIAL SPEC. ST. STL. TYPE 304			
		TR.			
		CHK.			
		APPR.	JAC	1-14-60	
		APPR.		1-15-60	
		MET.			
NAME COMB		(SINGLE ELEMENT) (FLOW TEST RIG 347)			
PART NO. B9-50-1118					

BREAK SHARP EDGES
REMOVE ALL BURRS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES.
TOLERANCES ON FINISHED
FRACTIONAL DIMENSIONS
TO BE $\pm 1/32$

✓ FINISH AS INDICATED
IN MICROINCHES.

(/1) MACHINE FINISH - ROUGH

(/10) FLAME CUT OR SAW

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This test was run with the same top and bottom core support configuration described in Sec. 4.4.5. Velocity distribution at a nominal flow rate of 300 gpm is shown in Fig. 4-18. Velocity distribution was within +10.2% and -13.2% of average. Overall pressure drop for this test at 350 gpm nominal flow rate was 18.1 ft of water.

4.4.7 Test #7 - Style 9c Inlet, Style 9a Outlet (1st Pass)

In a further attempt to improve upon channel flow distribution, a style 9c inlet configuration was tested in combination with a style 9a outlet. Style 9c hole configuration is shown in Fig. 4-19.

The velocity flow distribution for this test was within +12.3% and -13.9% of average at a nominal flow rate of 300 gpm. Velocities are shown plotted in Fig. 4-20. Overall pressure drop for this combination of top and bottom plate configurations was 21.6 ft of water at 350 gpm nominal flow rate.

4.4.8 Test #8 - Style 9c Inlet, Style 9b Outlet (2nd Pass)

For this test, a combination of a first pass bottom plate configuration (Fig. 4-19) and a second pass top plate configuration (Fig. 4-21) was used. Channel to channel velocity distribution at 300 gpm nominal flow rate, plotted in Fig. 4-22, was within +13.2% and -15.4% of average. Both lattices were within -2.4% of average. Overall pressure drop for this combination of top and bottom plates was 34 ft of water at 350 gpm nominal flow rate which did not match the required control rod pressure drop of 29 ft of water.

4.4.9 Test #9 - Style 9c Inlet, Style 9a Outlet - with Modification To End Fixture (1st Pass)

In an attempt to improve upon the low flow velocities obtained in channels adjacent to the lattices (channels B, C, O and P) in the previous test (Sec. 4.4.7), the end fixture struts were moved from over the third and sixteenth plates to over the fifth and fourteenth plates (see Fig. 4-23 and 4-5).

The effect of this modification was to raise the flow velocities of the deficient channels nearer to the average. Flow velocities were then within +15.8% and -10.1% of average. Figure 4-24 is a plot of velocity distribution at a nominal flow rate of 300 gpm. Overall pressure drop for this test was 23.5 ft of water at a nominal flow rate of 350 gpm.

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Fig. 4-18 Stationary Element Flow Distribution (Style 9 Inlet and 9a Exit with Modifications to End Fixture) - 1st Pass

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Fig. 4-19 Dwg. AES-474, Style 9c - Inlet Support Plug - 1st Pass

INLET PLUG

ALCO		ALCO PRODUCTS, INC.	
NUCLEAR POWER ENGINEERING DEPT.		SCHENECTADY, N. Y., U. S. A.	
SCALE: FULL	REV: AES-381	DR. A. PETTA	4-5-60
MATERIAL SPEC. CARBON STL.		TR.	
		CHK.	
		APPR. JAC	4-5-60
		APPR. JAC	4-5-60
		MET.	
NAME: PLUG (SINGLE ELEMENT) STYLE 9C (FLOW TEST RIG) SM-2			
PART NO. AES-474			

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Fig. 4-20 Stationary Element Flow Distribution (Style 9c Inlet and 9a Exit) - 1st Pass

Fig. 4-22 Stationary Element Flow Distribution (Style 9c Inlet and 9b Exit) - 2nd Pass

Fig. 4-23 Dwg. C9-50-1120, End Fixture Assembly

Fig. 4-24 Stationary Element Flow Distribution (Style 9c Inlet and 9a Exit) - 1st Pass

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4.4.10 Test #10 - Style 9c Rev. A Inlet (Rotated 90°) Style 9a Outlet (1st Pass)

Since flow distribution was still not within acceptable limits, Style 9c used in test #9 was modified as shown in Fig. 4-19. The modification consisted of enlarging the 1/2-in. holes to 9/16 in. and adding a 3/64 x 45° chamfer to the 5/8 in. holes in the first and fifth rows. The same exit plug (9a) was used for this test.

One further change was made for this test. The inlet plug (9c Rev. A) was rotated 90° to a position shown in Fig. 4-25. The position of the inlet plug before 90° rotation is also shown. This change was made because analysis of the previous test showed that the channels deficient in flow were behind solid land areas of the plug where no flow holes existed. By rotating the plug 90°, the deficient channels received better flow distribution because they were now sharing more flow holes than in the previous test.

Velocity distribution at 300 gpm nominal flow rate, shown plotted in Fig. 4-26, was within +7 and -9.6% of average. Overall pressure drop for this test was 24.6 ft of water at 350 gpm nominal flow rate.

4.4.11 Test #11 - Style 9c Rev. A Inlet (Original Position), Style 9a Exit (1st Pass)

Before this test was run pads were added to both end fixture assemblies as shown in Fig. 4-5 and 4-23. The addition of these pads resulted in continuous pad support across the side plate of the fuel element. The purpose of these pads was to simplify the fabrication of the end fixtures. Testing was done to check the hydraulic effects of the change.

The results of this test are shown plotted in Fig. 4-27. Flow velocities were within +7.7% and -10.7% at a nominal flow rate of 300 gpm. Overall pressure drop for this combination of top and bottom core plate configurations was 22.5 ft of water at 350 gpm nominal flow rate.

As a result of this test, the final design of the end fixture assemblies was decided upon and is shown in Fig. 4-5 and 4-23. This combination of top and bottom plates was chosen for final first pass design. A complete tabulation of data is included in Table 4-2.

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Fig. 4-25a Flowhole Orientation Before Rotation

Fig. 4-25b Flowhole Orientation After 90° Rotation

Fig. 4-26 Stationary Element Flow Distribution (Style 9c Rev. A
 Inlet - Rotated 90° and 9a Exit) - 1st Pass

Fig. 4-27 Stationary Element Flow Distribution (Style 9c Rev. A Inlet and 9a Exit) - 1st Pass

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TABLE 4-2
VELOCITY (FPS) FLOW DISTRIBUTION FOR COMBINATION OF 1ST PASS
BOTTOM AND TOP PLATE CONFIGURATIONS

Channel Identification	Nominal Element Flow, GPM				
	200	250	300	350	400
A	11.5	14.5	17.4	20.5	23.6
B	10.3	12.8	15.3	17.8	20.5
C	10.1	12.7	15.2	17.4	19.9
D	12.1	15.1	18.0	21.0	24.0
E	11.4	14.4	17.3	20.1	22.9
F	11.1	13.8	16.5	19.1	21.8
G	10.3	12.7	15.1	17.5	19.8
H	11.8	15.0	17.8	20.7	23.6
*I	12.1	15.2	18.1	21.0	23.9
J	11.6	14.8	17.6	20.5	23.4
/K	10.1	12.6	15.0	17.3	19.5
L	11.4	14.4	17.2	19.8	22.6
M	11.1	14.0	16.6	19.3	21.9
N	11.6	14.6	17.5	20.3	23.1
O	11.1	13.8	16.4	19.0	21.4
P	10.6	13.2	15.8	18.3	20.8
Q	11.6	14.8	17.6	20.6	23.5
Lattice X	11.4	14.3	17.1	19.6	22.4
Y	11.8	15.0	17.8	20.6	23.6
Average	11.2	14.1	16.8	19.5	22.2

* = High +7.7%

/ = Low -10.7%

Static Pressure

Drop Across

Element, ft H₂O at 80°F

7.96

12.3

17.1

22.4

28.6

4.4.12 Test #12 Style 12a Inlet, Style 9a Exit (1st Pass)

For this test, a combination of style 12a inlet and 9a outlet was used to simulate the top and bottom core plate configurations. The inlet plug (see Fig. 4-28) was rotated 90° from the position shown. The outlet plug is shown in Fig. 4-15. This combination was used in an attempt to better the distribution results obtained in the previous test with 90° inlet plug rotation (Sec. 4.4.10).

Overall pressure drop at 350 gpm nominal flow rate was 22.9 ft of water. Velocity distribution was within +6% and -8.4% of average and is shown in Fig. 4-29 (reading in channel 0 should be discarded because a faulty instrument probe was discovered after testing. Flow velocity in the active "x" lattice was 6% below average.

4.4.13 Test #13 - Style 9c Rev. A (modified) Inlet, Style 9a Outlet (1st Pass)

For this test style 9c Rev. A inlet was modified and used in combination with a style 9a outlet (Fig. 4-15). The inlet plug was identical to style 9c Rev. A except that four breakout holes were added in an attempt to improve upon flow distribution results obtained in test #11 (Sec. 4.4.11).

Distribution results are shown plotted in Fig. 4-31. Velocities were within +9.3% and -14.4% of average. Overall pressure drop for this combination of top and bottom plates was 21.7 ft of water at a nominal flow rate of 350 gpm.

4.4.14 Test #14 - Style 9c Rev. A (modified) Inlet, Style 9b Outlet (2nd Pass)

Bottom and top core configurations were style 9c Rev. A (modified) and style 9b respectively. This test was conducted to find out what a combination made up of first and second pass inlet and exit would give in the way of pressure drop. Distribution results are shown plotted in Fig. 4-31 and were within +10% and -8.2% of average. However, both "x" and "y" lattices received below average flow.

Overall pressure drop at 350 gpm nominal flow rate was 32.8 ft of water which was 10.3% higher than the required 29 ft of water.

Fig. 4-29 Stationary Element Flow Distribution (Style 12a Inlet and 9a Exit) - 1st Pass

Fig. 4-30 Stationary Element Flow Distribution (Style 9c Rev. A
 Modified Inlet and 9a Exit) - 1st Pass

Fig. 4-31 Stationary Element Flow Distribution (Style 9c Rev. A
 Modified Inlet and 9b Exit) - 2nd Pass

4.4.15 Test #15 - Style 13 Inlet, Style 9b Outlet (2nd Pass)

For this test a style 13 inlet plug (Fig. 4-32) was used in combination with a style 9b outlet plug (Fig. 4-21). This style 13 design featured both chamfer and full taper on the majority of flow holes. This was done in an attempt to improve flow distribution and reduce overall pressure drop.

Velocity distribution at 350 gpm nominal flow rate is shown plotted in Fig. 4-33. Flow velocities were within +5.8% and -8.2% with only two channels (channel 0 and Y) reading lower than the required 6% minimum. At 350 gpm nominal flow rate, the overall pressure drop was 31.6 ft of water.

4.4.16 Test #16 - Style 13 Rev. A Inlet, Style 9b Exit (2nd Pass)

A modification was made to the style 13 inlet plug for this test (see Fig. 4-32). The modification consisted of enlarging the four holes around the central locating hole and tapering the element positioning slot. The modification was made to improve both flow distribution and pressure drop results obtained in the previous test. The exit plug was the same as used in the previous test (Sec. 4.4.15).

Overall pressure drop for this combination of bottom and top core support configurations was 31.1 ft of water at the nominal flow rate of 350 gpm. Velocity flow distribution was within +5.01% and -9.0% of average at a nominal 350 gpm flow rate. The modification made above brought a low channel up but further reduced the "Y" lattice. The results are plotted in Fig. 4-34.

4.4.17 Test #17 - Style 13 Rev. A Inlet, Style 9b Exit Rotated 180° (2nd Pass)

This test was run to provide verification of proper instrumentation or probe readout. By rotating the unsymmetrical exit plug 180°, the hydraulic flow pattern was rotated 180°, since everything else was symmetrical. The results of this test are plotted in Fig. 4-35 and when compared with the results of the previous test (test #16 - Fig. 4-34), indicates only a very slight difference which can be attributed to the instruments and probes. Thus the validity of the instrumentation was established.

4.4.18 Test #18 - Style 13 Rev. A Inlet, Style 9b Rev. A Exit (2nd Pass)

For the final second pass configuration tested, the exit plug (style 9b) was modified as shown in Fig. 4-21. This modification was made in an attempt to match the control rod pressure drop of 29 ft of water and also

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Fig. 4-32 Dwg. B9-50-2450, Style 13 - Inlet Support Plug (2nd Pass)

Fig. 4-33 Stationary Element Flow Distribution (Style 13 Inlet and 9b Exit) - 2nd Pass

Fig. 4-34 Stationary Element Flow Distribution (Style 13 Rev. A Inlet and 9b Exit) - 2nd Pass

Fig. 4-35 Stationary Element Flow Distribution (Style 13 Rev. A
Inlet and 9b Exit Rotated 180°) - 2nd Pass

to improve upon the low velocity distribution in the "Y" lattice and adjacent channels. The modification consisted of enlarging flow holes which distribute flow to the "Y" lattice and adjacent channels.

Flow distribution results are plotted in Fig. 4-36. Flow velocities were within +4.3% and -4.5% of average with definite improvement seen in the "Y" lattice and adjacent flow channels. Overall pressure drop at 350 gpm nominal flow rate was 28.8 ft of water which was within 0.6% of the target value. A complete tabulation of data at various flow rates is given in Table 4.3.

Testing terminated when the results of this test were obtained. The final second pass combination of top and bottom core support configuration is based on this combination of style 13 Rev. A (Fig. 4-32) inlet and style 9b Rev. A (Fig. 4-21) exit.

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Fig. 4-36 Stationary Element Flow Distribution (Style 13 Rev. A Inlet A and 9b Rev. A Exit) - 2nd Pass

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TABLE 4-3
VELOCITY (F.P.S.) FLOW DISTRIBUTION FOR COMBINATION OF 2ND PASS
BOTTOM AND TOP PLATE CONFIGURATIONS

Channel Identification	Nominal Element Flow, GPM				
	200	250	300	350	400
A	10.9	13.8	16.5	19.3	21.9
/B	10.75	13.3	16.0	18.5	21.1
C	11.10	13.6	16.3	18.8	21.1
D	11.6	14.4	17.3	20.0	22.6
E	11.4	14.1	16.7	19.5	22.2
F	11.4	14.2	16.8	19.5	22.3
G	10.9	13.3	16.1	19.0	21.5
H	11.4	14.1	16.7	19.3	21.6
I	11.4	14.2	16.75	19.5	21.9
J	11.1	13.6	16.3	19.0	21.3
K	10.75	13.4	16.2	18.6	21.0
L	11.3	14.2	17.1	19.8	22.5
M	11.1	14.1	16.8	19.5	22.0
N	11.5	14.5	17.3	19.9	22.7
O	11.3	14.1	16.7	19.3	21.8
P	11.1	13.9	16.8	19.6	22.2
*Q	11.5	14.4	17.3	20.2	22.6
Lattices { X	11.1	13.9	16.6	19.2	21.6
Y	11.4	14.2	16.8	19.6	22.2
Average	11.3	13.9	16.6	19.3	22.0

* = high +4.3%

/ = Low -4.5%

Static Pressure

Drop Across

Element, ft H₂O at 80°F

10.3	15.7	21.6	28.8	36.2
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5.0 CONCLUSIONS

The basic objectives of this test program were successfully attained. Final bottom and top core support configurations for the first pass were styles 9c (Fig. 4-19) and 9a (Fig. 4-15) respectively. Flow distribution for this combination of bottom and top plates was within +7.7% and -10.7% of average. The low pressure drop was a predominant factor in choosing this combination. This pressure drop was 17.1 ft of water (80°F) at a flow rate of 272 gpm. Final second pass top and bottom plate configurations were style 13 Rev. A (Fig. 4-32) and style 9b (Rev. A (Fig. 4-21) with overall pressure drop of 28.8 ft H₂O across this combination, missing the target value of 29 ft of water by only 0.6%. Velocity distribution for this combination was +4.3% and -4.5% of average which was within the design requirements of +6% for second pass. The target value of 29 ft of water across the second pass stationary element was arrived at by matching the control rod pressure drop which was experimentally determined before stationary element testing commenced.

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6.0 BIBLIOGRAPHY

1. APAE Memo No. 235, "SM-2 Reactor Core and Vessel Review Report, August 25, 1959 to December 14, 1959," December 24, 1959.
2. APAE Memo No. 223, "SM-2 Reactor Core and Vessel Review Report, May 28, 1959 to August 24, 1959," September 8, 1959.
3. APAE Memo No. 243, "SM-2 Reactor Core and Vessel Monthly Report, December 15, 1959 to February 5, 1960," February 19, 1960.