CATAWBA NUCLEAR STATION
UNITS 1 AND 2

MCGUIRE NUCLEAR STATION
UNITS 1 AND 2

Reactor Vessel Cavity Seal Test Results

January 18, 1985

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INTRODUCTION

As a result of a failure of the refueling cavity water seal at Haddam Neck Plant, described in NRC IE Bulletin No. 84-03, "Refueling Cavity Water Seal", all power reactor facilities are required to evaluate the potential for and the consequences of a refueling cavity water seal failure. The response to the bulletin was transmitted to the NRC via Mr. H. B. Tucker's letter dated November 21, 1984. In this response, Duke committed to perform a series of tests designed to determine the ultimate capacity of the seals. The objective of this test program is to subject the seal configuration used at Catawba and McGuire to a series of tests to determine the ultimate capacity of the seals. The minimum acceptance criteria, as stated in the bulletin response, will be a seal capacity to withstand twice the normal static head of water, with cavity full of water.

SCOPE

Perform seal capacity tests in accordance with Appendix A, Reactor Vessel Cavity Seal Testing Procedure. Ultimate capacity of seals shall be determined for varying widths and differential elevations of annulus opening. The varying widths and elevations are intended to envelope as-built dimensions of all units at Catawba and McGuire. From the test results, safety factors based on the normal head of water, can be determined for each unit and compared to the minimum acceptance critera.

CONCLUSIONS

1. The seal layout with horizontal and vertical alignment as shown in the cross section in Figure 1 has a safety factor greater than four. Testing was stopped when a safety factor of four was reached.

2. The minimum safety factor based on the worst case as-built dimensional conditions for McGuire and Catawba Units are as follows:

   McGuire Unit 1 - Minimum Safety Factor = 2.2
   McGuire Unit 2 - As-built dimensions have not been recorded, this is scheduled for the next outage.

   Catawba Unit 1 - Minimum Safety Factor = 3.0
   Catawba Unit 2 - Under Construction

   Duke is committed to maintain the minimum acceptance criteria of a seal capacity to withstand twice the normal static head of water.

RECOMMENDATIONS

1) McGuire Unit 1 and Catawba Unit 1 meet the minimum acceptance criteria with regard to seal capacity, seal modifications are not required.

2) McGuire Unit 2, as-built dimensions are scheduled to be recorded during the next outage. As-built dimensions will be evaluated against the test results to determine the minimum factor of safety and compared to the minimum acceptance criteria.

DISCUSSION

1. Test Fixture

The test fixture was fabricated in accordance with drawing number DBF-1, contained in Appendix B. The test was constructed to represent the actual seal seating surfaces as shown in the cross section in Figure 1. Figure 3 compares the Reactor Vessel cavity seal installation to the head of the test fixture. Note, the dimensions and shape of both the primary shield wall and the reactor vessel flange are maintained. The head of the test fixture is adjustable allowing the annulus width and the top elevations to be varied. A series of tests were conducted varying these parameters to obtain results that will envelope the as-built conditions. A hydraulic device was utilized to apply load through a loading bar to a portion of the seal surface to simulate the normal hydrostatic loads.

The total load and loading increments are monitored by a digital multimeter and a strip recorder through a load cell. The load cell is placed between the hydraulic device and loading bar. Table 5 provides a summary of all equipment used in the tests.

2. Seal Test Specimens

Test specimens of the Catawba-McGuire cavity seal were obtained from Presray Company of Pauling, New York. The test specimens were fabricated to the exact specifications of the actual seal construction. The elastomer used is EDPM E603 a Presray material with a durameter rating of 60. Three test specimens were used for the testing. Specimen No. 1 and No. 2 were 48 inches long and fitted for inflation. Specimen No. 5 was 24 inches long and was not inflatable. Figure 2 provides dimensions measured from the actual test specimens.

3. Seal Testing Procedure

The seal testing was performed in accordance with Appendix A, Reactor Cavity Seal Testing Procedure. Tables 1 through 4 summarize the tests conditions. Table No. 1 lists the test head setup and seal conditions for each test. Table No. 2 and 3 list the test head setup for vertical and horizontal alignment and the test seal conditions respectively. Table No. 4 list the testing failure criteria. Test 1 through 10 are pull through test using seal No. 5, uninflated. Tests 11 through 18 are push through test using seal No. 1 and variations in air pressure. Test 19 through 24 are also push through test but seal No. 2 is used in place of seal No. 1. It should be noted that the pull through loading is applied through a 1/2"Ø bar and the push through loading is applied at the center of the top flange of the seal specimen by a 3/4"Ø bar.

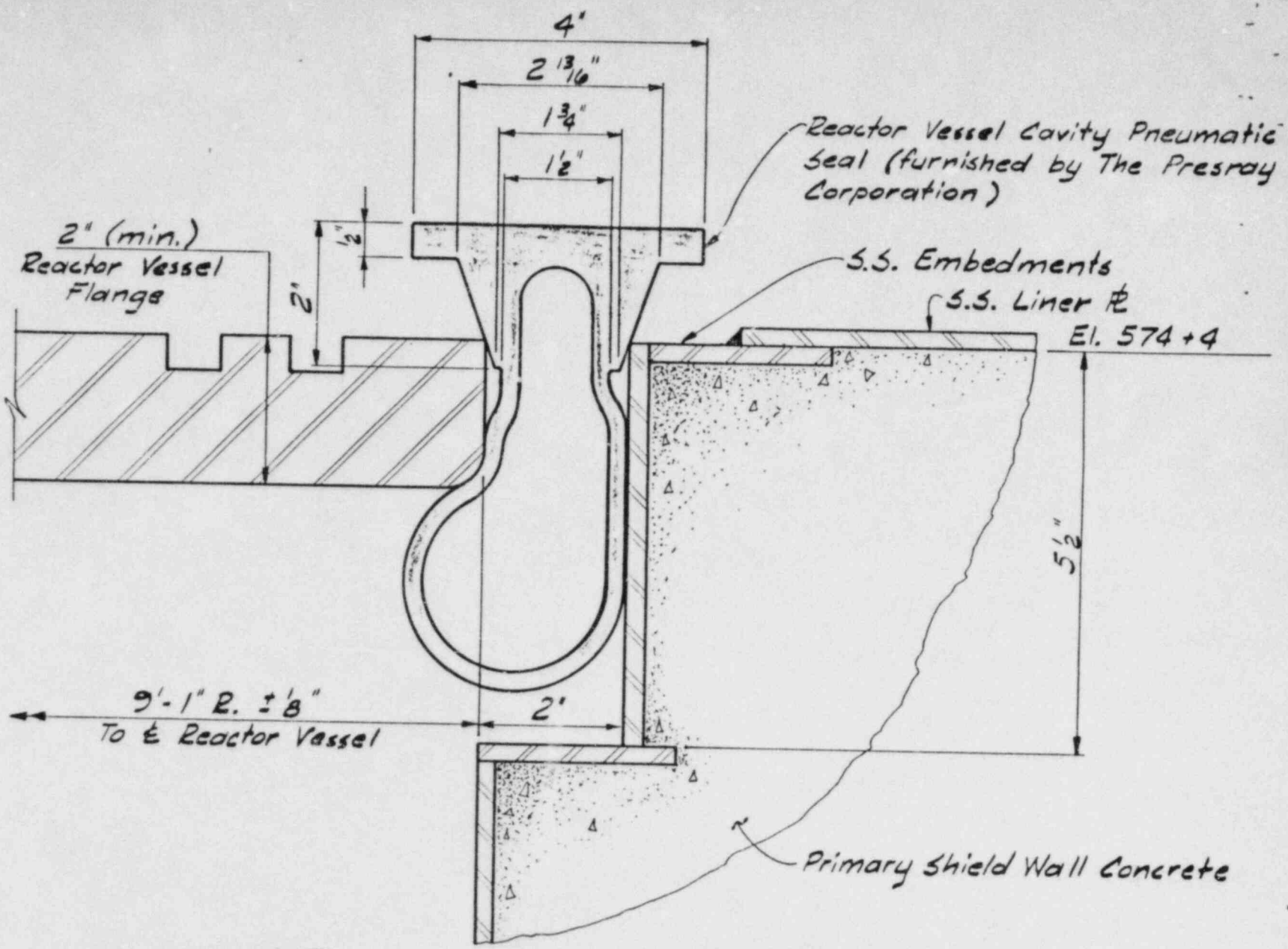


FIGURE 1

CATAWBA - McGUIRE

CAVITY SEAL

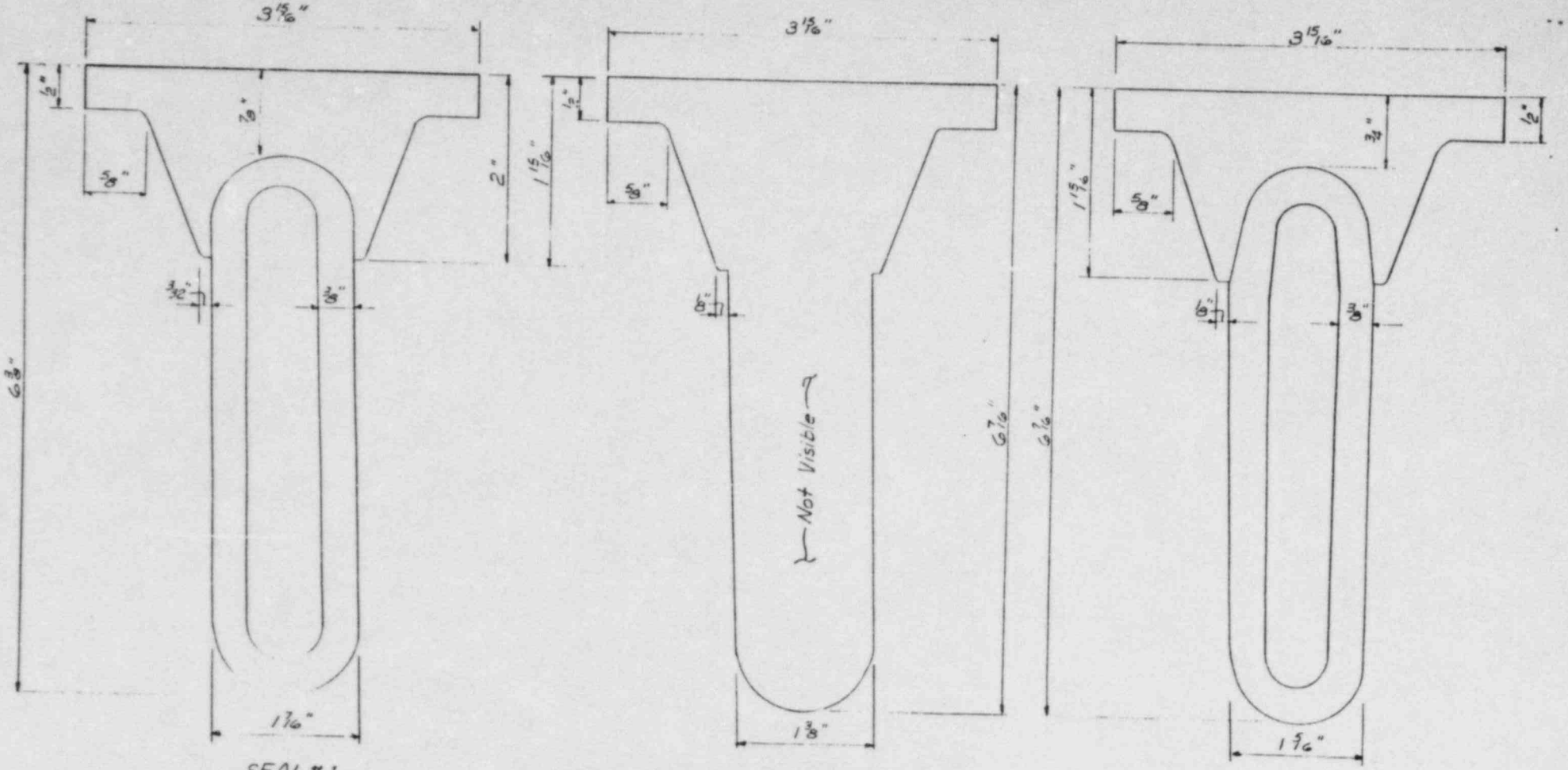
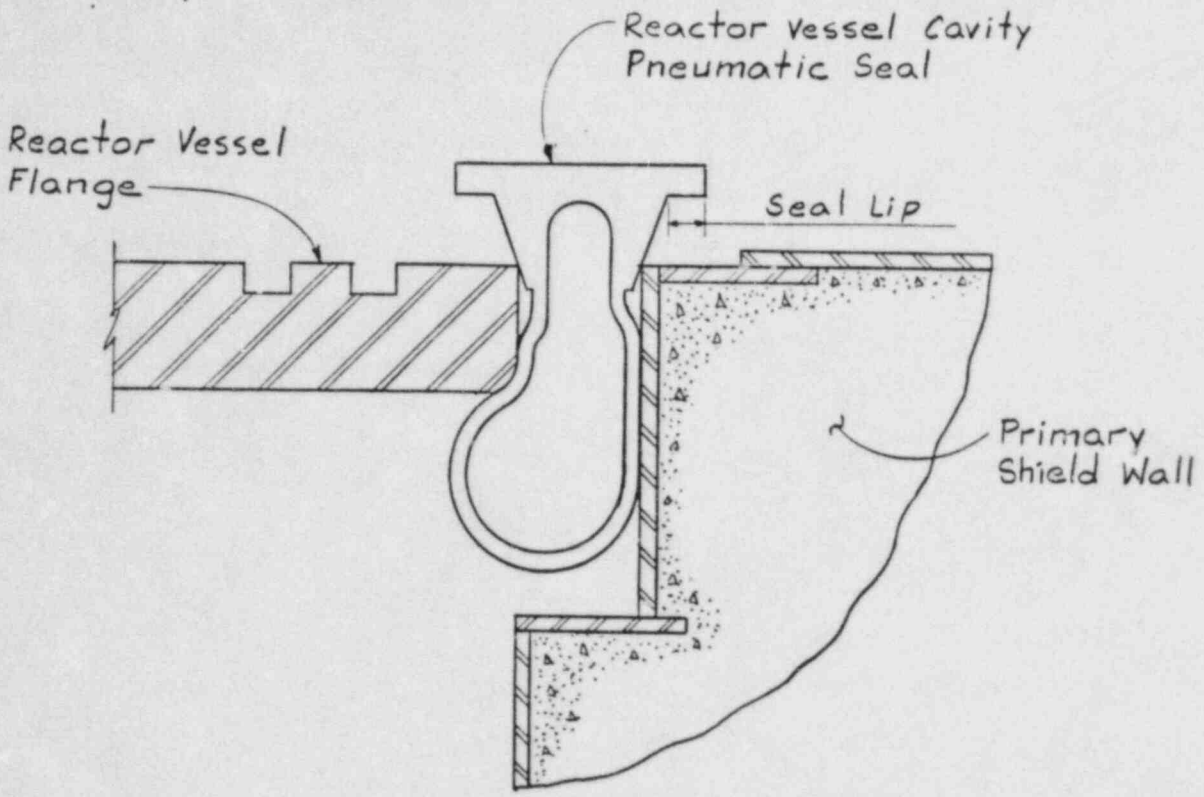
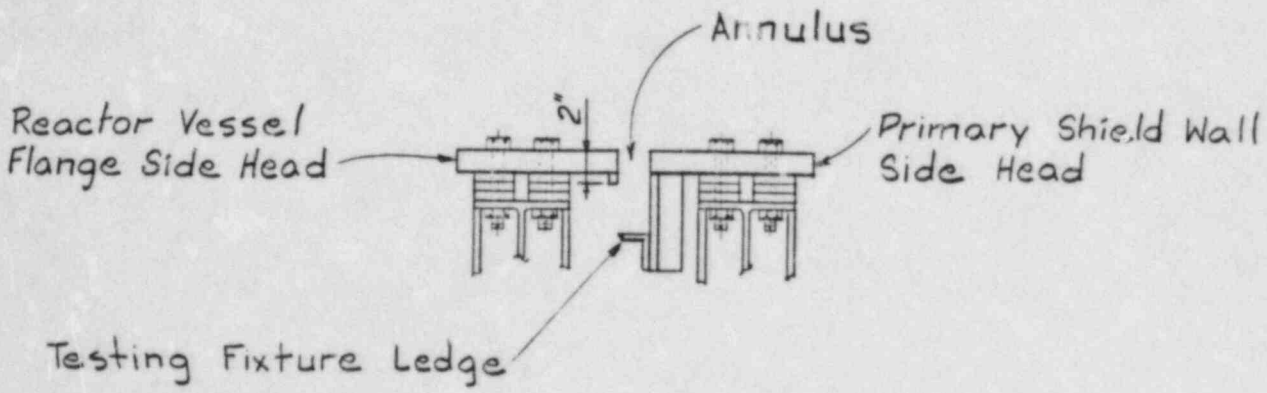

3 15/16"
1/2"
3/8"
5/8"
2"
6 3/8"
3/32"
3/8"
1 7/16"
SEAL #1
SN50252-1-1
PRS585-6
PRESRAY
3 15/16"
1/2"
1 15/16"
5/8"
1/8"
Not Visible
6 7/16"
1 3/8"
SEAL #2
SN50252-1-2
PRS585-6
PRESRAY
3 15/16"
1 15/16"
5/8"
3/4"
1/2"
1/8"
3/4"
1 9/16"
SEAL #5
SN50252-1-5
PRS585-6
PRESRAY

FIGURE 2



REACTOR VESSEL CAVITY
SEAL INSTALLATION



TESTING FIXTURE HEAD

Figure #3

TABLE 1

TEST SETUP CORRESPONDENCE TABLE

Test No.	Test Head Setup (See Table 2)	Test Seal Condition (See Table 3)
1	1	4
2	2	4
3	3	4
4	4	4
5	5	4
6	6	4
7	7	4
8	8	4
9	9	4
10	10	4
11	11	4
12	12	3
13	13	3
14	14	1
15	15	2
16	16	2
17	17	2
18	18	2
19	19	2
20	20	2
21	21	2
22	22	2
23	23	2
24	24	2

TABLE 2

TEST HEAD SETUP

Setup No.	Vertical Alignment Diff. In Elev. In Inches	Horizontal Alignment Gap Width In Inches	
		End 1	End 1
1	0.0	2"	2"
2	0.0	2 1/4	2 1/4
3	0.0	2 1/2	2 1/2
4	0.0	2 3/4	2 3/4
5	3/8 (Lower Lip Side)	2 3/4	2 3/4
6	3/8 "	2 1/2	2 1/2
7	3/8 "	2 1/4	2 1/4
8	1/2 "	2 1/4	2 1/4
9	1/2 "	2 1/2	2 1/2
10	1/2 "	2 3/4	2 3/4
11	0.0	2	2
12	0.0	2	2
13	0.0	2 1/4	2 1/4
14	0.0	2 1/4	2 1/4
15	0.0	2 1/2	2 1/2
16	0.0	2 3/4	2 3/4
17	1/4 (Lower Lip Side)	2 3/4	2 3/4
18	1/4 "	2 1/2	2 1/2
19	1/4 "	2 1/4	2 1/4
20	1/4 "	2	2
21	1/2 "	?	2
22	1/2 "	2 1/4	2 1/4
23	1/2 "	2 1/2	2 1/2
24	1/2 "	2 3/4	2 3/4

TABLE 3

TEST SEAL CONDITIONS

Condition No.	Seal Condition
1.	A: Inflate seal to design pressure of 35 psi. B: Load seal through loading head with 3/4"Ø rod only. C: Test to be continued until a sustained maximum load is reached.
2.	A: Inflate seal to design pressure of 35 psi. B. Load seal through loading head with 3/4"Ø rod only. C: Deflate seal as loading approaches a sustained maximum loa D: Continue loading seal to a new sustained maximum load. E: Reinflate seal and load until a sustained maximum load is reached.
3.	A: Seal uninflated. B: Load seal through loading head with 3/4"Ø rod only. C: Test to be carried to a sustained maximum load is reached
4.	A: Load seal with pull through device. B: Test to be carried to failure, or until a sustained maximum load is reached.

TABLE 4

FAILURE CRITERIA

1. Seal is forced through opening.

2. Seal material is damaged in such a way as to be incapable of carrying additional load or substantial leakage would be expected in operation.

3. Considering the nature of the test load, if it becomes reasonable to expect that the seal would fail in actual operation or that leakage would become substantial, the test shall be stopped and the load recorded to that point will be called the failure load.

4. When a loading cycle is stabilized at a value which yields a safety factor of 4.0 or above, the test may be stopped.

TABLE NO. 5
EQUIPMENT DATA SHEET

Load Cell:
Make: Strainsert
Universal Flat Load Cell
Capacity: 25. kips
Model: FL25U(c) 25PMT
S/N: 05384-1

Digital Multimeter:
Make: Hewlett - Packard
Model: 3466A
S/N: 01843

Strip Recorder:
Make: Heath
Model: SR206
S/N: 39772

Power Supply:
Make: ACOPIAN
Model: K20D50

Air Supply:
Make: (Field Built)
S/N: MC1AC26631, calibrated 10-1-84

Loading Jack:
Make: OWATONNA Tool Co.
Capacity: 100 tons

Pull Device:
Weight: 54 lbs.

Pushing Device:
Weight: 108 lbs.

APPENDIX A

Reactor Vessel Cavity Seal Testing Procedure

CATAWBA NUCLEAR STATION
UNITS 1 & 2

MCGUIRE NUCLEAR STATION
UNITS 1 & 2

REACTOR VESSEL CAVITY SEAL TESTING PROCEDURE

Revision: 1
Date: 1/2/85

Revision No. 1
Date: 1/2/85

REACTOR VESSEL CAVITY SEAL TESTING PROCEDURE

PURPOSE

The purpose of this procedure is to establish the ultimate capacity of the reactor vessel cavity seal. This procedure provides the design of a testing fixture, the required tests,test methods, and the needed documentation as means to this end. It also serves as a partial response to IEB 84-03.

SCOPE

This procedure applies only to the Catawba and McGuire reactor vessel cavity seals. Units 1 and 2 of both plants use the same type of seal.

RESPONSIBILITIES

A. Design Engineering:

Design Engineering shall be responsible for the design of the tests, testing fixture, and evaluation of the test results. Design shall also aid McGuire Nuclear Production in the execution of the testing.

B. McGuire Nuclear Production:

McGuire Nuclear Production shall be responsible for construction of the test fixture, execution of the testing, and collection of the test data.

C. McGuire Nuclear Station Calibration Lab:

The Calibration Lab shall be responsible for the calibration of all test gages and the establishment of the pressure vs. force relationship for the loading system.

EQUIPMENT

A. Testing Fixture:

The testing shall be conducted using the test fixture shown on drawing DBF-1. The test head of the fixture shall be set up in accordance with the instructions in the procedures section of this procedure.

B. Test Air Supply:

An air supply is required for the implementation of the testing. The supply shall be capable of at least 55 psig and shall be adjustable over the range 0 to 55 psig. The supply shall be complete with a gage readable in 1 psig increments, accurate to $\pm$ 1% of the face reading, and connected in such a way as to read the pressure in the test seal.

C. Load Application Device:

The load shall be applied hydraulicly through the test head shown on drawing DBF-1. This device shall be capable of applying at least 5000 lbs. to the test head at a rate no greater than 1000 lbs./min.

D. Load Cell and Load Cell Monitoring Devices

The load application device shall be fitted with a calibrated load cell. The load cell shall be capable of accurately sensing loads in the 0-5000 pound range to a tolerance of ±1% of the measured load. The load call shall be monitored by a digital multimeter calibrated to read directly in pounds and a strip recorder. The strip recorder shall plot the load application history so that the machine's X-axis is recording time and the Y-axis is recording force in pounds.

E. Test Seals:

Five test seals will be provided by the Presray Co. Seals number 1 to 4 will be four feet long and fitted with air connections. These four seals can be used interchangeably in the test number 1 to 4 as outlined in the procedures section. Seal number 5 will be 2 feet long and be open at both ends. Seal 5 will be used only in test number 5 as outlined in the procedures section.

PROCEDURES

Table No. 1 lists all required tests and the conditions under which the tests are to be run. The loading rate of 1000 lbs./min. is the maximum rate at which load is to be applied to any test specimen. Table No. 4 lists the criterion by which failure is to be judged. The pressure corresponding to any of the criterion shall be listed as the failure pressure.

Data shall be recorded on the test data sheets provided in appendix A of this procedure. General information about the test should be recorded at the top of the form in the blanks provided. Load values shall be noted at the beginning and end of any significant seal deformation cycles, along with the necessary remarks to describe the particular features of the cycle. Strip recorder records shall be numbered and attached to the corresponding data sheet. Table No. 5 lists water head, uniform seal pressure, applied force, and implied safety for the seal specimens use for these tests. It is provided for reference only.

TABLE 1

TEST SETUP CORRESPONDENCE TABLE

Test No.	Test Head Setup (See Table 2)	Test Seal Condtion (See Table 3)
1	1	4
2	2	4
3	3	4
4	4	4
5	5	4
6	6	4
7	7	4
8	8	4
9	9	4
10	10	4
11	11	4
12	12	3
13	13	3
14	14	1
15	15	2
16	16	2
17	17	2
18	18	2
19	19	2
20	20	2
21	21	2
22	22	2
23	23	2
24	24	2

TABLE 2

TEST HEAD SETUP

Setup No.	Vertical Alignment Diff. In Elev. In Inches	Horizontal Alignment Gap Width In Inches	
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2	0.0	2 1/4	2 1/4
3	0.0	2 1/2	2 1/2
4	0.0	2 3/4	2 3/4
5	3/8 (Lower Lip Side)	2 3/4	2 3/4
6	3/8 "	2 1/2	2 1/2
7	3/8 "	2 1/4	2 1/4
8	1/2 "	2 1/4	2 1/4
9	1/2 "	2 1/2	2 1/2
10	1/2 "	2 3/4	2 3/4
11	0.0	2	2
12	0.0	2	2
13	0.0	2 1/4	2 1/4
14	0.0	2 1/4	2 1/4
15	0.0	2 1/2	2 1/2
16	0.0	2 3/4	2 3/4
17	1/4 (Lower Lip Side)	2 3/4	2 3/4
18	1/4 "	2 1/2	2 1/2
19	1/4 "	2 1/4	2 1/4
20	1/4 "	2	2
21	1/2 "	2	2
22	1/2 "	2 1/4	2 1/4
23	1/2 "	2 1/2	2 1/2
24	1/2 "	2 3/4	2 3/4

TABLE 3

TEST SEAL CONDITIONS

Condition No.	Seal Condition
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3.	A: Seal uninflated. B: Load seal through loading head with 3/4"Ø rod only. C: Test to be carried to a stable maximum load is reached.
4.	A: Load seal with pull through device. B: Test to be carried to failure, or until a stable maximum load is reached.

TABLE 4

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1. Seal is forced through opening.

2. Seal material is damaged in such a way as to be incapable of carrying additional load or substantial leakage would be expected in operation.

3. Considering the nature of the test load, if it becomes reasonable to expect that the seal would fail in actual operation or that leakage would become substantial, the test shall be stopped and the load recorded to that point will be called the failure load.

4. When a loading cycle is stabilized at a value which yields a safety factor of 4.0 or above, the test may be stopped.

TABLE 5

EQUIVALENT SEAL LOADS

Loading by a 3/4" rod 43 3/4" long
Annulus opening 2"

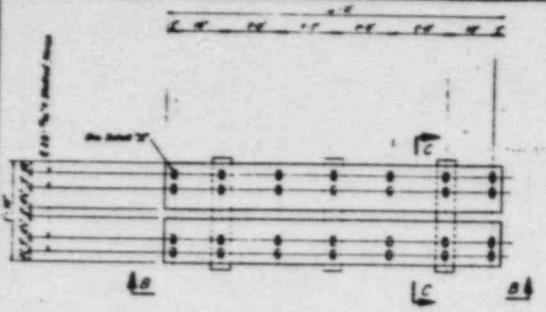
Water Head	Pressure (psi)	Force (lbs)	Safety Factor
24'	10.4	910.0	1.
30'	13.0	1137.5	1.25
40'	17.3	1513.8	1.67
50'	21.7	1898.8	2.08
60'	26.0	2275.0	2.50
70'	30.3	2651.3	2.92
80'	34.7	3036.3	3.33
90'	39.0	3412.5	3.75
100'	43.3	3788.8	4.17

Loading by a bar 23 3/4" long
Annulus opening 2"

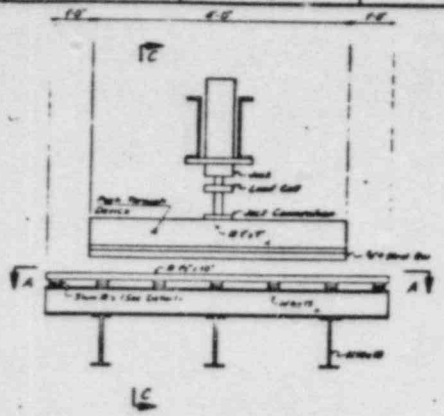
Water Head	Pressure (psi)	Force (lbs)	Safety Factor
24'	10.4	494.0	1.0
30'	13.0	617.5	1.25
40'	17.3	821.8	1.67
50'	21.7	1030.8	2.08
60'	26.0	1235.0	2.50
70'	30.3	1439.3	2.92
80'	34.7	1648.3	3.33
90'	39.0	1852.5	3.75
100'	43.3	2056.8	4.17

APPENDIX B

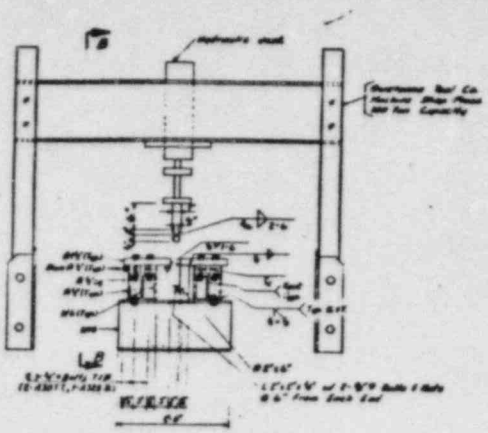
Test Fixture Drawing DBF-1



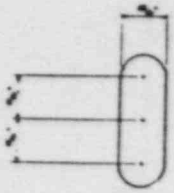
SECTIONAL PLAN A-A



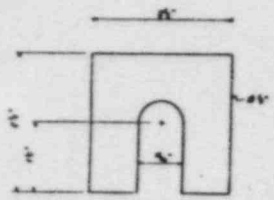
ELEVATION B-B



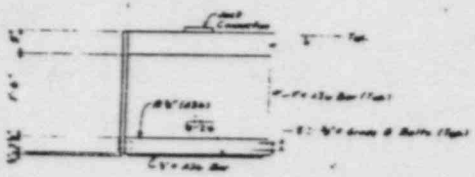
SECTION C-C



DETAIL "A"



SHIM B DETAIL



PULL THROUGH C-C

INTERCHANGEABLE WITH PUSH-THROUGH DEVICE

		BURNS POWER COMPANY ALL PLANTS	
		REACTOR VESSEL CAVITY SEAL TESTING DEVICE	
		DWG NO CBF-1	
NO	REVISIONS		