MASTER

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Program: Cover Gas Seals

AEC Task: 11 - FFTF-LMFBR Seal Test Program

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I. PROJECT OBJECTIVES

The objectives of this program are to: (1) conduct static and dynamic tests to demonstrate or determine the mechanical performance of full-size (cross section) FFTF fuel transfer machine and reactor vessel head seals intended for use in a sodium vapor - inert gas environment, (2) demonstrate that these FFTF seals or new seal configurations provide acceptable fission product and cover gas retention capabilities at Clinch River Breeder Reactor Plant (CRBRP) operating environmental conditions other than radiation, and (3) develop improved seals and seal technology for the CRBRP to support the national objective to reduce all atmospheric contaminations to low levels.

The leakage and/or permeation of reactor cover gas into the FFTF head cavity through elastomer seals will be calculated for each seal. Examination of head-region penetrations and evaluation of the designs are currently underway. The material permeation measurements and/or seal permeation measurements generated on this program will be used for the calculations.

An additional objective will be to conduct a feature test on the IVHM inflatable seals to: (1) verify acceptable operational performance under environmental conditions anticipated in FFTF service, and (2) demonstrate satisfactory long-term operation (80,000 linear feet of travel) for the seals at the anticipated CRBRP rotating plug speed. A feature test to assess the performance of the FFTF Instrument Tree inflatable seals will be conducted.

A special test will be conducted by AI and the Hanford Engineering Development Laboratory (HEDL), wherein the permeation of a set of elastomer seals will be measured by AI and the leakage of a metallic seal measured by HEDL.

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The test fixtures and gases will be exchanged between the two facilities, and the tests repeated, to compare the measuring techniques of the two laboratories.

II. MAJOR ACCOMPLISHMENTS DURING FISCAL YEAR 1974

Reciprocating and rotary dynamic testing of seals generated considerable new test data concerning the leakage, compression set, and wear characteristics of various seal types and materials under specific conditions of compression, temperature, lubrication, travel, and surface finish. Both short-term (information tests) and longer-term (demonstration tests) are being conducted.

Compression set testing of O-ring seals yielded additional long-term data on Buna N, urethane, ethylene propylene, and silicone materials. (These tests have established some maximum operating temperature-time relationships for the materials.)

Permeability-solubility testing has been completed on 20 elastomer samples. This information is now being used as a basis for evaluating the leakage performance of seals under the dynamic test program.

Assembly and checkout of all static O-ring test fixtures were completed, and all are now on test.

A review of various lubricants was conducted to select a backup lubricant for evaluation in the seal test program. The evaluation included lubricant-elastomer compatibility, friction-temperature performance, and temperature-time stability.

A comprehensive survey of the gas boundary leakage in the FFTF has been completed, and the report is being prepared. Test fixtures were designed for static inflatable seal and molded-in-metal static seal tests. The fabrication of the Instrument Tree inflatable seal feature test fixture was started, and the Test Plan was issued for comments.

A permeation test of the IVHM inflatable seal was completed. Compatibility and bond strength tests, to determine the seal bond failure mode, were started. Development Requirements Specification, DRS 32.06, for conducting tests on IVHM inflatable seals under CRBRP conditions, was received from Westinghouse; the AI Test Plan was written and later revised to include comments by Westinghouse. The test program has started.

The test procedure for the AI-HEDL Comparative Seal test was approved. Fabrication of the AI-HEDL comparative seal test fixture was completed, and the first phase of the Comparative Seal Test, using two Buna N O-rings (Compound 366Y), was completed at AI, and the fixture shipped to HEDL. The HEDL test fixture containing a metal seal was subsequently received by AI and set up to test. The test is still continuing.

An interim report, TI-707-810-013, was prepared, summarizing the seal test data generated to date, and recommending seal materials and types, temperature limitations, seal gland sizes, percent compression, etc., for use in FFTF design and fabrication.

III. PROGRESS DURING REPORT PERIOD

A. DYNAMIC TESTING

Testing is continuing on all phases of the dynamic seal test program to provide meaningful test data on a time schedule consistent with FFTF and CRBRP program requirements. Two types of seal tests are being run in the program — demonstration tests and information tests. The demonstration tests are evaluating the performance of various seal types when tested under conditions representative of those specified for FFTF seal design conditions. Testing is about 6 months in duration for each group of test seals. Information tests are measuring the short-term performance of various seal types under broader ranges of seal application conditions, to determine appropriate new guidelines and/or seal standards for use in the design of current or future reactor systems.

Program redirection was given by HEDL/ARD in April to include urethane seals in the test program. Concurrently, the half of the information test matrix which included the second lubricant tests was deleted. Only selected comparison tests will be made with the second lubricant, WSX 87788.

Individual tests which were completed or initiated are discussed in the following sections.

1. Reciprocating Seal Tests

a. Demonstration Tests No. 3 and 4

The two reciprocating tests completed six months of testing without evidence of gross leakage, as noted in Table 1. The test fixtures were disassembled and the seals examined for wear. Figure 1 shows all the seals removed from Test No. 3, and Figures 2 and 3 are closeup views of the typical Buna N T-seal and a Buna N Q-seal, respectively, showing the absence of wear.

Figure 4 shows all the seals removed from Test No. 4, and Figure 5 is a close-up view of a typical EPR Quad-ring showing the lack of wear. No evidence of wear was noted on the EPR T-seal removed from the same test.

b. Demonstration Tests No. 5 and 6

Two new tests (5 and 6) were set up with urethane and Buna N seals, as noted in Table 1. These tests are a part of the revised test program described in the last monthly report.

2. Rotating Seal Tests

a. Demonstration Tests No. 5 and 6

The test fixtures were disassembled, and the Buna N seals removed and examined. Evidence of wear was negligible.

b. Demonstration Tests No. 7 and 8

These tests, containing EPR seals as noted in Table 2, completed 18,125 ft of travel with no evidence of gross leakage.

c. Demonstration Tests No. 9 and 10

Two new demonstration tests were started with urethane O-rings, as shown in Table 2. These tests also are part of the new matrix.

d. Information Tests No. 18, 19, 20, and 21

The three rotating information tests were stopped at the end of the test cycle after completing 108,100 revolutions (56,535 ft of travel) as noted in Table 3. (Test No. 19 had been stopped earlier because of high friction forces which developed after about 12,500 ft of travel.) The fixtures have not been disassembled at this time, but it is anticipated that the high friction forces on Test No. 19 were produced by the 20% compression of the seals with a resultant high wear rate on the urethane.

TABLE 1
RECIPROCATING DEMONSTRATION SEAL TEST

Test	Seals	Compression (%)	Shaft Finish (rms)	Temperature (° F)	Lubricant	Seal Travel
No. 3	Q rings (3) Buna N Parker Seal	10	8	150	DC55M	6210 ft (4660 cycles)
	T seals (3) Buna N Parker Seal	10	8	150	DC55M	6210 ft (4660 cycles)
No. 4	Q rings (3) EPR Minnesota Rubber	10	8	150	DC55M	6210 ft (4660 cycles)
	T seals (3) EPR Parker Seal	10	8	150	DC55M	6210 ft (4660 cycles)
No. 5	T seals (3) Urethane Parker Seal	10	8	100	DC55M	Checkout phase
	T seals (3) Buna N Green Tweed	10	8	100	DC55M	Checkout phase
No. 6	T seals (3) Urethane Parker Seal	10	8	150	WSX8788	Checkout phase
	T seals (3) Buna N Green Tweed	10	8	150	WSX8788	Checkout phase

Figure 1. Reciprocating Seal — Demonstration Test No. 3B

Figure 2. Parker Seal T-Seal Removed from Reciprocating Demonstration Test No. 3
after Six Months of Testing

9006-40182

Figure 3. Parker Seal Q-Ring Removed from Reciprocating Demonstration Test No. 3
after Six Months of Testing

9006-40184

9006-40183

Figure 4. Reciprocating Seal — Demonstration Test No. 4

9006-40185

Figure 5. Minnesota Rubber Quad-Ring Removed from Reciprocating Demonstration
Test No. 4 after Six Months of Testing

TABLE 2
ROTATING SEAL DEMONSTRATION TEST

Test	Seals	Com- pression (%)	Shaft Finish (rms)	Temper- ature (° F)	Lubricant	Seal Travel	Comments
No. 5	Q rings (4) Buna N Parker Seal	10	8	150	DC55M	32,070 ft (61,325 cycles)	Test completed.
No. 6	O rings (4) Buna N Minnesota Rubber	10	8	150	DC55M	32,070 ft (61,325 cycles)	Test completed.
No. 7	Quad rings (3) EPR Minnesota Rubber *	10	8	150	DC55M	18,125 ft (34,653 cycles)	Test in progress; no indication of leakage.
No. 8	O rings (3) EPR Parker Seal *	10	8	150	DC55M	18,125 ft (34,653 cycles)	Test in progress; no indication of leakage.
No. 9	O rings (3) Urethane Parker Seal	10	8	100	DC55M	1,790 ft (3,423 cycles)	Test in progress; no indication of leakage.
No. 10	O rings (3) Urethane Parker Seal	10	8	150	DC55M	1,790 ft (3,423 cycles)	Test in progress; no indication of leakage

*Parker Seal Buna N (N741) outer seal to reduce end losses.

TABLE 3

ROTATING SEAL INFORMATION TESTS

Test	Seals	Com- pression (%)	Shaft Finish (rms)	Temper- ature (°F)	Lubricant	Seal Travel	Comments
No. 18	O ring (1) Urethane Minnesota Rubber	5	16	100	DC55M	56,535 ft (108,100 cycles)	Test completed.
	Q rings (2) Urethane Parker Seal	5	16				
No. 19	Quad ring (1) Urethane Minnesota Rubber	20	16	100	DC55M	12,400 ft (23,680 cycles)	Test rotation stopped. High torque forces.
	O rings (2) Urethane Parker Seal	20	16				
No. 20	O ring (1) Urethane Minnesota Rubber	5	4	100	WSX-8788	56,535 ft (108,100 cycles)	Test completed.
	Q rings (2) Urethane Parker Seal	5	4				
No. 21	Quad ring (1) Urethane Minnesota Rubber	20	4	100	WSX-8788	56,535 ft (108,100 cycles)	Test completed.
	O rings (2) Urethane Parker Seal	20	4	100			

3. Leakage Calculations

Tables 4 to 7 list all of the rotating Buna N, urethane, EPR, and silicone seal tests completed to date or currently running. Shown in the tables are the calculated data for the leakages of hydrogen, krypton, and xenon obtained from permeability data and an estimated geometry factor for an O-ring seal for comparison purposes with the measured leakage data. All tabulated measured data have been processed by the revised computer program which corrects for permeation losses of gas through the outer containment seal.

B. STATIC TESTING

1. Static Seal Tests

New static seal tests were set up with urethane O-rings to conform to the program redirection, and are operating under the following test conditions:

a. Demonstration Tests

Static seal tests, STA D-4 and D-5, were set up with urethane O-rings from Parker Seal and Minnesota Rubber. These seals are being tested at 100°F under 50% compression.

b. Information Tests

Static seal tests, STA I-4 and I-5, were set up with urethane O-rings from Parker Seal and Minnesota Rubber. These seals are being tested at 100 and 150°F at 10 and 20% compression.

Static information tests 3A, 3B, 3C, and 3D, which had been re-run with Buna N outer containment seals to reduce gas losses, were stopped after 2,184 hr and the fixtures were disassembled. Figures 6 and 7 are typical of the seals removed from test. The silicone seals showed compression sets ranging from 42 to 67% after the 3-month exposure at 300°F (Table 8). The Minnesota Rubber and Parker Seal Buna N O-rings showed about 95% and 60% set, respectively, but the Parker Seal O-ring (Figure 7) was found to be split in several places, although no gross leakage had been observed. Similar cracking of the Parker Seal Buna N had been observed earlier in the compression set testing of this type of seal at 150 and 200°F. This test confirmed the earlier conclusion that the high hardness, high modulus seals should not be used at high compression values.

TABLE 4
ROTATING BUNA N SEAL - TABULATION OF L VALUES
FROM ELASTOMER SEAL LEAKAGE TESTS

Seal Type	Elastomer*	Supplier	Test Type	Compression (%)	Finish (rms)	Lubricant	Leakage [†]					
							L _{H₂}		L _{Kr}		L _{Xe}	
							Meas.	Calc.	Meas.	Calc.	Meas.	Calc.
O	Buna N	PS	RoD-4	10	8	DC55M	41	78	26	20	35	24
O	Buna N	MR	RoD-6	10	8	DC55M	36	114	31	33	36	40
Quad	Buna N	MR	RoD-3	10	8	DC55M	112	114	29	33	41	40
O	Buna N	PS	RoD-5	10	8	DC55M	46	78	30	20	30	24
O	Buna N	PS	RoI-6	5	4	DC55M	-	90	51	23	25	28
O	Buna N	MR	RoI-7	20	4	DC55M	148	90	-	26	33	31
O	Buna N	MR	RoI-11	5	16	DC55M	-	131	8	38	-	46
O	Buna N	PS	RoI-12	20	16	DC55M	-	62	33	16	-	20
Quad	Buna N	MR	RoI-6	5	4	DC55M	91	131	-	38	-	46
Q	Buna N	PS	RoI-7	20	4	DC55M	-	62	19	16	-	20
Q	Buna N	PS	RoI-11	5	16	DC55M	122	90	-	23	24	28
Quad	Buna N	MR	RoI-12	20	16	DC55M	93	90	-	26	24	31

PS = Parker Seal

MR = Minnesota Rubber

Ro = Rotary

I = Information

D = Demonstration

L_{Kr} = Std cc/sec/linear in. of seal/atm ΔP of Kr x 10⁻⁸ (L_{H₂} and L_{Xe} similar units)

*150°F

†Listed values corrected for permeation leakage through outer fixture seal

TABLE 5
ROTATING URETHANE SEALS – TABULATION OF L VALUES
FROM ELASTOMER SEAL LEAKAGE TEST

Seal Type	Elastomer	Supplier	Test Type	Compression (%)	Finish (rms)	Lubricant	Leakage [§]					
							L _{H₂}		L _{Kr}		L _{Xe}	
							Meas.	Calc.	Meas.	Calc.	Meas.	Calc.
O	Urethane*	PS	RoD-9	10	8	DC55M	-	15	-	2	-	3
O	Urethane†	PS	RoD-10	10	8	DC55M	-	51	-	16	-	17
O	Urethane*	PS	RoI-16	5	4	DC55M	-	19	-	2.5	-	4
O	Urethane*	MR	RoI-17	20	4	DC55M	-	28	-	5	-	5
O	Urethane*	MR	RoI-18	5	16	DC55M	-	45	-	8	-	7.5
O	Urethane*	PS	RoI-19	20	16	DC55M	-	11	-	1.5	-	2
Quad	Urethane*	MR	RoI-16	5	4	DC55M	-	45	-	8	-	7.5
Q	Urethane*	PS	RoI-17	20	4	DC55M	-	11	-	1.5	-	2
Q	Urethane*	PS	RoI-18	5	16	DC55M	-	19	-	2.5	-	4
Quad	Urethane*	MR	RoI-19	20	16	DC55M	-	28	-	5	-	5
O	Urethane†	MR	RoI-2	20	4	DC55M	-	-	86	-	67	-
Q	Urethane†	PS	RoI-2	20	4	DC55M	150	-	-	-	-	-

PS = Parker Seal

MR = Minnesota Rubber

Ro = Rotary

l = Information

D = Demonstration

L_{Kr} = Std cc/sec/linear in. of seal/atm ΔP of Kr x 10⁻⁸ (L_{H₂} and L_{Xe} similar units)

*100° F

†150° F

§ Listed values corrected for permeation leakage through outer fixture seal

TABLE 6

ROTATING EPR SEALS - TABULATION OF L VALUES
FROM ELASTOMER SEAL LEAKAGE TESTS

Seal Type	Elastomer*	Supplier	Test Type	Compression (%)	Finish (rms)	Lubricant	Leakage [†]					
							L _{H₂}		L _{Kr}		L _{Xe}	
							Meas.	Calc.	Meas.	Calc.	Meas.	Calc.
O	EPR	MR	RoD-2	10	8	DC55M	79	420	460	170	246	279
O	EPR	PS	RoD-8	10	8	DC55M	-	313	-	130	-	247
Quad	EPR	MR	RoD-7	10	8	DC55M	-	420	-	170	-	279
Q	EPR	PS	RoD-1	10	8	DC55M	79	313	136	130	341	247
O	EPR	MR	RoI-1	5	4	DC55M	-	469	80	190	75	312
O	EPR	PS	RoI-5	20	4	DC55M	151	231	-	96	-	182
O	EPR	PS	RoI-8	5	16	DC55M	126	362	-	150	56	285
O	EPR	MR	RoI-9	20	16	DC55M	138	321	-	130	50	213
Q	EPR	PS	RoI-1	5	4	DC55M	258	362	-	150	-	285
Quad	EPR	MR	RoI-5	20	4	DC55M	-	321	83	130	64	213
Quad	EPR	MR	RoI-8	5	16	DC55M	-	469	101	190	-	312
Q	EPR	PS	RoI-9	20	16	DC55M	-	231	70	96	-	182

PS = Parker Seal

MR = Minnesota Rubber

Ro = Rotary

I = Information

D = Demonstration

L_{Kr} = Std cc/sec/linear in. of seal/atm ΔP of Kr x 10⁻⁸ (L_{H₂} and L_{Xe} similar units)

*150°F

†Listed values corrected for permeation leakage through outer fixture seal

TABLE 7
ROTATING SILICONE SEALS - TABULATION OF L VALUES
FROM ELASTOMER SEAL LEAKAGE TESTS

Seal Type	Elastomer*	Supplier	Test Type	Compression (%)	Finish (rms)	Lubricant	Leakage [†]					
							L _{H₂}		L _{Kr}		L _{Xe}	
							Meas.	Calc.	Meas.	Calc.	Meas.	Calc.
O	Silicone	PS	RoI-10	5	4	DC55M	-	13,055	644	6,800	-	7,685
O	Silicone	MR	RoI-13	20	4	DC55M	2,887	14,760	-	6,000	(26)	4,620
O	Silicone	MR	RoI-14	5	16	DC55M	-	22,140	-	9,000	-	6,930
O	Silicone	PS	RoI-15	20	16	DC55M	1,705	8,830	-	4,600	92	5,200
Quad	Silicone	MR	RoI-10	5	4	DC55M	325	22,140	-	9,000	100	6,930
Q	Silicone	PS	RoI-13	20	4	DC55M	-	8,830	481	4,600	-	5,200
Q	Silicone	PS	RoI-14	5	16	DC55M	-	13,055	-	6,800	-	7,685
Quad	Silicone	MR	RoI-15	20	16	DC55M	-	14,760	418	6,000	-	4,620

PS = Parker Seal

MR = Minnesota Rubber

Ro = Rotary

I = Information

D = Demonstration

L_{Kr} = Std cc/sec/linear in. of seal/atm ΔP of Kr × 10⁻⁸ (L_{H₂} & L_{Xe} similar units)

*300°F

†Listed values corrected for permeation leakage through outer fixture seal

Figure 6. Static Information Test No. 3 — Re-run, 300°F
Region A

9006-40209

Figure 7. Static Information Test No. 3 — Re-run, 300°F
Region C

9006-40210

TABLE 8
COMPRESSION SET OF SEALS REMOVED FROM STATIC INFORMATION
TEST NO. 3 (RERUN) AFTER 2184 HOURS

Elastomer	Diam (in.)	Location	Com- pression* (%)	Vendor	Thickness		Groove Depth	Hardness		Com- pression Set (%)
					Pre, t_0	Post, t_1		Pre	Post	
Buna N	8	A	44.3	MR	0.210	0.120	0.117	70	82	96.8
Buna N	8	B	44.7	PS	0.205	0.152	0.116	75	84	59.6
Buna N	8	C	44.7	PS	0.206	0.155	0.116	76	85	56.7
Buna N	8	D	45.2	MR	0.210	0.120	0.115	71	80	94.7
Silicone	4	A	9.0	MR	0.211	0.198	0.191	74	74	65.5
Silicone	4	B	8.6	PS	0.208	0.200	0.192	77	74	50.0
Silicone	4	C	19.5	PS	0.206	0.183	0.169	76	74	62.2
Silicone	4	D	20.0	MR	0.210	0.182	0.168	75	72	66.7
Silicone	2	A	9.0	MR	0.210	0.202	0.191	72	70	42.1
Silicone	2	B	8.6	PS	0.207	0.200	0.192	76	75	46.7
Silicone	2	C	19.5	PS	0.205	0.183	0.169	75	74	61.1
Silicone	2	D	20.4	MR	0.211	0.190	0.167	73	67	47.7

*For a nominal 0.210 in. cross section O-ring

2. Leakage Calculations

As described in a preceding report, the leakage values can be calculated knowing the seal geometry, percent compression, temperature, and material permeability. Table 9 compares these calculated values with the measured values for both H₂ and Kr. Where indicated (*), the measured values have been calculated using the revised computer program which compensates for gas losses through the outer, containment seal. The remaining values are being calculated.

3. Compression Set

The 80 and 95% confidence limits were calculated for the compression set of O-ring seals from Parker Seal EPR (Compounds E529 and E692) and silicone (Compound S684), and Minnesota Rubber silicone (Compound 71417). Figures 8 to 11 show the graphical representation of the compression set data, and Tables 10 to 13 show the calculated confidence limits. Additional confidence limit values will be added when calculated.

C. PERMEABILITY TESTS

Preparation of the Summary Report has begun.

D. GAS BOUNDARY LEAKAGE CALCULATIONS

The completed report is in final typing and is planned for release next month.

E. INSTRUMENT TREE INFLATABLE SEALS TEST

The fixture is completed. The labor dispute at the supplier is over but a revised delivery for the silicone and nitrile seals from the original order has not been received. The EPDM seals are scheduled for a September 17, 1974 delivery. Comments on the AI Test Plan by Westinghouse have not been received.

F. COMPARATIVE LEAK TEST

The testing of HEDL metal seal was stopped when it was apparent that a significant amount of leakage of gas from the sampling reservoir was occurring through the silicone rubber O-rings. Permission was given by HEDL personnel to attempt to seal the system (externally) to prevent this loss. Without disturbing the metal seal, Buna N O-rings were forced into the gap between the top and bottom portions of the test fixture, and the closure bolts and spacers were sealed with a RTV silicone cement.

TABLE 9

STATIC O-RING SEAL TESTS - TABULATION OF H₂ AND L_{Kr} VALUES
FROM ELASTOMER SEAL LEAKAGE TESTS

Seal Type	Elastomer	Supplier	Test Type	Compression (%)	Finish (rms)	Lubricant	Leakage			
							L _{H2}		L _{Kr}	
							Meas.	Calc.	Meas.	Calc.
O	Buna N [†]	PS	STA-D-1	50	16	DC55M	25	23	5	6
O	Buna N	MR		50	16	DC55M	-	35	-	10
O	Buna N	MR	STA-1-1A	10	8	DC55M	81	114	27	33
O	Buna N	PS	STA-1-1B	10	32	DC55M	65	78	3	20
O	Buna N	PS	STA-1-1C	20	8	DC55M	43	62	12	16
O	Buna N	MR	STA-1-1D	20	32	DC55M	24	90	8	26
O	EPR [†]	PS	STA-D-2	50	16	DC55M	90*	90	35*	38
O	EPR	MR		50	16	DC55M	-	120	-	48
O	EPR	PS	STA-1-2A	10	8	DC55M	120*	315	70*	130
O	EPR	MR	STA-1-2B	10	32	DC55M	135*	420	60*	170
O	EPR	MR	STA-1-2C	20	8	DC55M	210*	320	75*	130
O	EPR	PS	STA-1-2D	20	32	DC55M	110*	230	60*	96
O	Silicone [§]	PS	STA-D-3	50	16	WSX 8788	470*	3,265	104*	1,700
O	Silicone	MR		50	16	DC55M	-	5,900	-	2,400
O	Silicone	MR	STA-1-3A	10	8	DC55M	-	19,680	-	8,000
O	Silicone	PS	STA-1-3B	10	32	DC55M	-	11,520	-	6,000
O	Silicone	PS	STA-1-3C	20	8	DC55M	-	8,640	-	4,500
O	Silicone	MR	STA-1-3D	20	32	DC55M	-	14,760	-	6,000

EPR = Ethylene propylene rubber

STA = Static

PS = Parker Seal

I = Information

MR = Minnesota Rubber

D = Demonstration

L_{Kr} = Std cc/sec/linear in. of seal/atm ΔP of Kr x 10⁻⁸L_{H2} = Std cc/sec/linear in. of seal/atm ΔP of H₂ x 10⁻⁸

*Listed values corrected for permeation leakage through outer fixture seal

† = 150°F § = 300°F

Figure 8. Compression Set of Parker Seal O-Ring Seals, EPR, Compound E529

9006 4097

Figure 9. Compression Set of Parker Seal Co. O-Ring Seals, Ethylene Propylene, Compound E692

9006-4098

Figure 10. Compression Set of Parker Seal Co. O-Ring Seals, Silicone, Compound S684

Figure 11. Compression Set of Minnesota Rubber O-Ring Seals,
Silicone, Compound 71417

TABLE 10
CONFIDENCE LIMITS - TEST DATA FOR COMPRESSION SET OF PARKER
SEAL EPR O-RINGS (E529) AT 150°, 200°, AND 250°F

Temp (°F)	Time (hr)	Compression Set		Confidence Limits			
		Measured	Calculated*	80%		95%	
150	To be tested						
200	168	5.8	In test				
	336	8.6					
250	168	54.3	54.0	53.2	55.0	52.3	55.8
	336	62.3	62.6	61.7	63.5	60.8	64.5
	672	72.0	72.5	71.5	73.6	70.5	74.6
	1344	84.8	84.0	82.7	85.3	81.5	86.4
	2688	97.0	97.3	97.3	95.6	98.9	100.5

*Least squares fit.

TABLE 11
CONFIDENCE LIMITS – TEST DATA FOR COMPRESSION SET OF PARKER
SEAL EPR O-RINGS (E692) AT 150°, 200°C, AND 250°F

Temp (°F)	Time (hr)	Compression Set		Confidence Limits			
		Measured	Calculated*	80%		95%	
150	168	6.1	8.2	5.3	12.7	3.7	18.2
	336	11.7	9.7	6.5	14.5	4.7	20.1
	672	13.2	11.4	7.8	16.8	5.7	22.9
	1344	15.5	13.5	9.2	19.8	6.7	27.0
	2688	16.5	15.8	10.6	23.7	7.6	32.8
	5376	15.1	18.7	12.1	28.9	8.5	41.1
200	168	17.7	17.4	15.1	20.1	13.4	22.6
	336	21.9	22.4	19.6	25.6	17.6	28.5
	672	29.9	28.8	25.4	32.7	22.9	36.3
	1344	33.6	37.1	32.6	42.1	29.4	46.7
	2688	52.8	47.7	41.7	54.5	37.4	60.7
	5376	59.3	61.3	53.0	70.8	47.1	79.6
250	168	26.4	27.0	24.3	30.0	22.2	32.7
	336	34.1	34.2	31.0	37.7	28.6	40.8
	672	43.7	43.3	39.4	47.5	36.5	51.3
	1344	55.2	54.8	49.9	60.2	46.3	64.9
	2688	75.3	69.4	62.9	76.5	58.1	82.9
	5376	81.7	87.9	79.1	97.7	72.5	106.5

*Least squares fit.

TABLE 12
CONFIDENCE LIMITS – TEST DATA FOR COMPRESSION SET OF PARKER
SEAL SILICONE O-RINGS (S684) AT 150°, 200°, AND 250° F

Temp (°F)	Time (hr)	Compression Set		Confidence Limits			
		Measured	Calculated*	80%		95%	
200	168	16.2	15.6	13.5	17.9	12.1	20.0
	336	21.1	20.4	18.0	23.2	16.2	25.8
	672	25.6	26.9	23.7	30.4	21.5	33.5
	1344	31.5	35.3	31.2	39.9	28.2	44.1
	2688	48.2	46.3	40.8	52.7	36.7	58.5
	5376	64.0	60.9	53.0	70.0	47.3	78.4
150	168	8.2	10.74	6.67	17.30	4.53	25.47
	336	13.6	11.84	7.63	18.37	5.34	26.24
	672	16.5	13.05	8.58	19.85	6.10	27.90
	1344	13.6	14.38	9.45	21.88	6.72	30.75
	2688	19.4	15.85	10.21	24.59	7.15	35.12
	5376	13.6	17.46	10.84	28.13	7.37	41.41
250	168	27.4	26.65	21.32	33.31	17.79	39.92
	336	33	35.45	28.85	43.54	24.42	51.45
	672	44.2	47.15	38.74	57.39	33.04	67.30
	1344	69.5	62.72	51.53	76.34	43.94	89.52
	2688	95.5	83.43	67.92	102.49	57.48	121.10
	5376	97.5	110.98	88.78	138.73	74.09	166.25

*Least squares fit.

TABLE 13
CONFIDENCE LIMITS - TEST DATA FOR COMPRESSION SET OF
MINNESOTA RUBBER SILICONE (71417) O-RINGS

Temp (° F)	Time (hr)	Compression Set		Confidence Limits			
		Measured	Calculated*	80%		95%	
150	To be tested						
200	168	12.9	To be calculated				
	336	19.1					
	672	22.0					
	1344	23.4					
	2856	38.3					
	5376	40.6					
250	168	26.5	26.9	24.2	29.9	22.3	32.5
	336	32.3	33.5	30.5	36.9	28.2	39.9
	672	45.2	41.8	38.1	45.8	35.4	49.3
	1344	50.7	52.1	47.5	57.1	44.1	61.5
	2688	67.7	64.8	58.9	71.4	54.5	77.2
	5376	77.5	80.8	72.8	89.7	66.9	97.6

*Least squares fit.

Testing was resumed and fairly linear leak rate values are being obtained. Table 14 summarizes the test readings after 338 hr.

TABLE 14
HEDL METAL SEAL LEAK RATE MEASUREMENTS

Time (hr)	H ₂ (ppm, meas)
55	38
122	90
215	138
312	205
338	250

These concentrations of H₂ give a leak rate of 5.7×10^{-8} cc/sec of Ar/1% H₂ gas at 39.5 psig differential. Assuming that the Ar and the H₂ exhibit similar flow characteristics, and reducing the pressure differential to 1 atm, the approximate total leak rate was calculated to be 1.4×10^{-6} cc/sec/atm ΔP .

G. CRBRP ROTATING PLUG SEAL FEATURE TEST

1. Adhesive Shear Tests

Additional pull tests were conducted on sections of inflatable seal cemented to stainless steel using Chemlock 304 adhesive and smeared with various lubricants. The time and temperature exposure is indicated in Table 15 along with the apparent shear stress in the bond at the time when pulling was stopped to prevent tearing of the rubber section.

TABLE 15
RESULTS OF PULL TESTS ON IVHM SEAL-ADHESIVE-METAL BOND

Adhesive	Lubricant	Time	Temperature	Shear Strength
Chemlock 304	DC55M	12 wk	165°F	>66 psi
Chemlock 304	WSX 8788	12 wk	165°F	>71 psi
Chemlock 304	None	12 wk	165°F	>72 psi
Chemlock 304	DC55M	1 mo	150°F	>96 psi
Chemlock 304	WSX 8788	1 mo	150°F	>164 psi

The first three samples are the last ones from the original test matrix started in February. The last two samples are the first results from the Chemlock 304 performance matrix which will continue for 16 months or longer. All results show continuing excellent performance of the Chemlock 304.

2. Compatibility Tests

Compatibility or weight change tests of seal materials and adhesives with various lubricants at 100 and 150°F are being conducted. Also, lubricant weight changes at those temperatures are being observed. Tables 16, 17, and 18 show the results to date and indicate future data points. Originally, tests of this type were conducted at 165°F to accelerate effects. The 100 and 150°F tests give data within the range that inflatable seals will operate. The 140 RTV is in the matrix as it is still used on the IVHM seal. Glycerin was a candidate lubricant when the test was started but has since been dropped from consideration based primarily on its high evaporation and high starting friction. The Chemlock 304 shows low absorption of the lubricants while 140 RTV absorbs considerable DC55M at all the temperatures. This absorption of DC55M by the 140 RTV is currently being investigated as a possible mechanism that contributed to the failure of the adhesive bond during testing of the IVHM seal.

3. Lubrication Testing

The wear and lubricity tests in support of the CRBRP seal use has been completed and is summarized in Table 19. Note that DC55M was the only grease that did not experience a shearing of the overload pin on the test fixture during startup after a dwell. DC55M was recommended for use on the CRBRP seal because of low friction and wear, good thermal stability, good compatibility with the seal rubber and Chemlock 304 adhesive, ready availability and favorable operating experience with inflatable seals and with other seals in the LMFBFBR general seal test program.

4. Seal Installation and Removal Development Using Chemlock 304 Adhesive

With the selection of Chemlock 304 to cement the seals in the glands for the CRBRP test, it became necessary to develop the procedures and processes and to draft them into a process specification. The removal procedures were first developed using flat plates and seal sections, as described last month. These procedures were demonstrated using a straight 3-ft section of seal gland machined

TABLE 16
RESULTS OF WEIGHT CHANGE TEST ON SEAL ASSEMBLY
MATERIALS (Soaked at 100° F in Various Lubricants)

Soak Time Days		10	20	30	60	90
Material	Lubricant	Percent Weight Change				
140RTV	DC55M	14.5	31.6			
140RTV	WSX8788	1.0	0.9			
140RTV	Glycerin	-0.2	-0.2			
Chemlock 304	DC55M	0.3	0.6			
Chemlock 304	WSX8788	0.4	0.7			
Chemlock 304	Glycerin	-0.1	-0.1			
BFG Rubber	DC55M	-1.2	-2.8			
BFG Rubber	WSX8788	-4.0	-5.6			
BFG Rubber	Glycerin	0.3	0.6			

TABLE 17
RESULTS OF WEIGHT CHANGE TEST ON SEAL ASSEMBLY
MATERIALS (Soaked at 150°F in Various Lubricants)

Soak Time Days		10	20	30	60	90
Material	Lubricant	Percent Weight Change				
140RTV	DC55M	17.8	37.0			
140RTV	WSX8788	0.9	0.2			
140RTV	Glycerin	-0.5	-0.5			
Chemlock 304	DC55M	1.1	1.9			
Chemlock 304	WSX8788	0.5	0.9			
Chemlock 304	Glycerin	0.5	1.0			
BFG Rubber	DC55M	-2.0	-5.9			
BFG Rubber	WSX8788	-6.0	-9.0			
BFG Rubber	Glycerin	0.8	0.4			

TABLE 18
WEIGHT CHANGE OF SEAL LUBRICANTS
DURING THERMAL SOAKING IN AIR

Lubricant	Temp (° F)	Percent Weight Change				
		Soak Time, Days				
		10	20	30	60	90
WSX8788	100	-0.02	-0.02	-0.03		
WSX8788	150	-0.6	-0.6	-0.7		
DC55M	100	-0.6	-0.6	-0.6		
DC55M	150	-0.9	-0.9	-1.0		

TABLE 19

CRBRP LUBRICANT WEAR EVALUATION FOR INFLATABLE SEALS
 (Nitrile O-Rings, 4 in. ID x 0.210 in. Cross Section,
 50 fpm at 150°F, 10% Squeeze on O-Rings,
 80,000-ft life travel minimum)

Lubricant	Travel (ft)	Drag (lb/in.)	O-Ring		
			Weight Change	Radial ΔD , in.	Longitudinal ΔD , in.
WSX8788, W/5% MoS ₂	60,000	<4	+0.7%	Negligible	+0.006
DC55M, W/5% MoS ₂	103,000	<2.5	Negligible	+0.002	+0.002
MoS ₂ Bonded Dry Lube (Perma Slick) 0.0007 in.	1,025	2 to shear of pin ⁽¹⁾	+0.2%	Negligible	Negligible
Glycerin Test ⁽¹⁾	10,300	<2.0 ⁽¹⁾	Negligible	+0.001	+0.002
Glycerin Test ⁽²⁾	86,355	2-3.5 ⁽³⁾	Negligible	-0.001	+0.001
WSX8788 ⁽¹⁾	87,000	<2.0 ⁽⁴⁾	+0.5%	Negligible	+0.001
DC55M ⁽¹⁾	84,100	<2.0 ⁽⁵⁾	+0.3%	Negligible	-0.001
WSX8788 ⁽²⁾	90,000	<2.4 ⁽⁶⁾	+0.7%	+0.001	+0.001
DC55M ⁽²⁾	85,200	<1.9 ⁽⁷⁾	+0.6%	Negligible	+0.001

(1) A pin shears at 8 lb/in. drag.

(2) Stopped over weekend. Pin sheared at 70°F on Monday.

(3) Stopped for 2.5 hr. Pin sheared at 80°F.

(4) Left at room temperature overnight and pin sheared when restarted.

(5) Left at room temperature for five hours and restarted with 2.0 lb/in. drag. Then left for weekend (65 hr) and restarted with 2.4 lb/in. drag.

(6) Left at 68°F overnight and 2 five minute dwell. Sheared pin each time.

(7) Left at 150°F for 5 min dwell and restarted with 2.4 lb/in. drag then at 70°F overnight and 2 five minute dwells with 2.4 lb/in. starting drag.

for this use. Figure 12 shows the operation which involves cutting a window in the seal, inserting a pry bar, lifting the seal, cutting clean through it and then separating the adhesive-metal band with a putty knife while prying the seal up. Residual Chemlock 304 can be softened with Oakite Stripper 157 and scraped from the metal. Specification ST0620NA0095, describing the process in detail, is being prepared.

The installation procedure using Chemlock 304 was developed and tried on the 3-ft gland section and then used to install the seals in the test rig. It, too, is described in the above specification being prepared. The steps are summarized as follows and as shown in Figures 13, 14, 15, 16, 17, and 18.

- 1) Mix 250 gm of the 2-part Chemlock 304 adhesive, put it into a squeeze tube, attach the extruding key, flatten the tube nozzle and weigh the tube assembly, plus gauze to be used for cleanup (Figure 13).
 - 2) Extrude an even band of adhesive into the gland and spread, using the spreader tool. Keep adhesive away from the inflation port but put some around the inflation stem (Figures 14, 15, and 16).
 - 3) Pick the seal up, insert the stem into the port and lay the entire seal in the gland (Figure 17).
 - 4) Using the wide seal-seating roller, press the seal down to seat the seal under the retaining beads (Figure 18). Start at the inflation stem and seat 3 to 4 in. at a time followed by rolling with a 3-in.-diam by 1/4-in.-wide rounded roller, not shown, to press the center of the seal base against the adhesive and to force air out. Proceed around the whole seal in this manner.
 - 5) Weigh the tube assembly and gauze with wipings. Use $135 \text{ gm} \pm 15 \text{ gm}$ to give a 0.030-in.-thick adhesive layer.
5. Seal Installation and Removal Development Using 140 RTV Adhesive

During preparation of the test rig for the CRBRP test, the inner seal which was bonded in the gland with 140 RTV was mistakenly removed from the gland. The peel-pull effort to remove the seal was 10 to 20 lb. The inflation stem flange (molded into the seal) was bent 15 degrees during removal. One superficial scratch on the side of the seal was noted. This removal action prompted

a. Starting Cutout

9006-40191

Figure 12. Removal of Epoxy Bonded Inflatable Seal
(Sheet 1 of 4)

b. Cutout Complete

9006-40190

Figure 12. Removal of Epoxy Bonded Inflatable Seal
(Sheet 2 of 4)

c. Cutting through Seal

9006-40188

Figure 12. Removal of Epoxy Bonded Inflatable Seal
(Sheet 3 of 4)

d. Removing Seal with Putty Knife/Pry Bar
Figure 12. Removal of Epoxy Bonded Inflatable Seal
(Sheet 4 of 4)

9006-40187

Figure 13. Adhesive Preparation

9006-40195

9006-40196

Figure 14. Adhesive Application

Figure 15. Adhesive Spreading

9006-40197

Figure 16. Adhesive Application In Inflation Stem Region

9006-40198

Figure 17. Seal Inflation Stem Insertion

9006-402000

Figure 18. Use of Seal Seating Roller

9006-40203

development of a seal cleanup procedure to prepare the seal for reinstallation. The chemicals reported on last month for cleanup of a gland after removal of a 140 RTV banded seal were used to clean the adhesive and DC55M from the seal. An overnight soak of a section of scrap seal with adhesive on it in Cee Bee C105B demonstrated that no damage was done to the seal rubber while the adhesive dissolved completely. The removed seal was cleaned using Moore M-6 solvent for DC55M grease and the C105B for the adhesive with about a 1- to 2-hr soak. The softened 140 RTV was scraped off using a plastic chisel-shaped tool.

Pull-test samples, using sections of seal and sections of stainless steel plate from which 140 RTV had been cleaned, were made up using Chemlock 304 adhesive to see if the cleanup affected the bond. One was pulled after a 3-day cure and one after a week at 150°F. The rubber started to tear in both cases at greater than 65 psi shear stress at the cement bond. The cleanup, therefore, showed no effect on the bond.

A revision to the IVHM seal installation specification which used 140 RTV (ST062NA0087) will be made to incorporate removal and cleanup information so that it is available if needed.

6. CRBRP Test Operations

The AI Test Plan (Westinghouse TP 32.06) was revised to incorporate comments by Westinghouse and was reissued. A development test procedure for use by AI laboratory personnel was written and issued.

The inner seal inflation stem flange was straightened to 8 degrees bend and the seal was installed in the test rig using the procedures developed on the 3-ft test section. The tubular seating press was used and required considerable effort (~130 lb) to push the seal below the retaining ridges in the gland. Also, a hydraulic locking and bubble trapping effect was noted to occur if each 3- to 4-in. section was not fully seated before proceeding to the next 3- to 4-in. section. About 158 gm of adhesive for 19 ft of seal was used which should result in 0.036-in.-thick adhesive. The adhesive has in excess of a 2-hr pot life. The seating required 1 hr with 2 men working.

A roller type seating tool was developed using the 3-ft seal gland test section and some scrap seal sections. The amount of adhesive also was varied, and less adhesive resulted in less hydraulic lock while still providing a full bond area.

The outer seal was installed using the seal seating roller and less cement. The upper edges of the retaining ridge in the gland were lightly dabbed with adhesive to provide lubrication during seating. A total of 134 gm of adhesive for 19 ft of seal was used which results in 0.028-in.-thick adhesive. One man seated the seal in 1/2 hr.

After a 3-day cure, the seals were lubricated with DC55M; 57 gm was applied to the outer seal and 27 gm to the inner seal. The top cover was put in place and tilted to build in ± 0.060 in. of vertical runout.

The non-uniform rotation cycle (1-1/2 CW, 1 CCW) required buildup of a timing switch box which is now installed. The run-in cycles are about to be performed. The installation will be leak checked, brought up to 150°F, started into tests which vary speed and inflation pressure, and then life cycled to 80,000 ft of total travel.

H. TOP SHIELD DIP SEAL PARAMETRIC TEST

The draft of the revised Test Plan for this subtask, TP-707-230-002, Rev. A, "Test Plan for the Dip Seal and Upper Annulus Sodium Deposition Test (TP 32.05)," was completed and submitted to ARD for review. The principal changes include:

- 1) Measurement of the attenuation of radioactive isotopes through the dip seal by providing argon with xenon in the lower annulus side of the dip seal, instead of the upper annulus side.
- 2) The addition of an un-notched blade dip seal configuration.
- 3) The addition of a test to determine the rate of mixing of fluid in the dip seal when subjected to oscillations.
- 4) The addition of radioactive tracer to the sodium and the subsequent measurement of the sodium deposition rate in the upper annulus by scanning.

The fabrication of the transparent dip seal was started.

The report, TI-707-230-009, "Dissolution of Na_2O Deposits by Flushing with Sodium," was written.

An analytical study of transport of radioactive gases through the dip seal was initiated.

IV. IMPACT ON LMFBR PROGRAMS

This program addresses itself specifically to: (1) the problems of cleaning surfaces exposed to sodium and the subsequent requalification of components for reuse, (2) the prevention of functional degradation by means of proper storage of cleaned components, (3) the development of practical storage containers, (4) the investigation and development of the alcohol/glycol ether sodium removal process and the associated process control (including reagent regeneration), (5) the development of local sodium removal tools and techniques, (6) the development of sodium removal by evaporation via vacuum chambers, and (7) the preparation of procedures to direct the various sodium cleaning operations.

VI. SCHEDULE

During the third quarter, the AI scope of effort on this program was re-directed by RRD to reflect an expansion of the sodium removal process development. The schedule of activities and milestones, Figure 19 was updated to reflect this redirection.

Figure 19

TASK 11 - FFTF-LMFBR Seal Test Program, Schedule and Milestones