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ABSTRACT

The FFTF-IVHM inflatable seal was tested, and met all requirements. The CRBRP inflatable seals are expected to operate at higher linear velocities and greater distortions, and accumulate more travel, than the IVHM installation. This document describes tests on the IVHM design to CRBRP conditions.

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I. TEST OBJECTIVE

The objective is to test the performance of FFTF-type inflatable seals to assure these seals will function reliably under the Clinch River Breeder Reactor Plant (CRBRP) operating conditions. The requirements of seal performance are:

- 1) Limited leak rate for radioactive isotopes in the cover gas; to maintain the concentration of these isotopes outside the seal within a permissible value during reactor operation and re-fueling when typical machining tolerances and runouts of the rotating plug system are used
- 2) Acceptable torque limits due to circumferential drag force
- 3) Maintainability, including ready inspection, lubrication renewal, and replacement capability consistent with required availability of the plant.

Satisfactory performance of the inflatable seals is vital to the reliability and to the high availability of the CRBRP, because of its role in the primary containment system. An extension of the on-going base technology program is required to cover specified operating conditions for the rotating plug system of the CRBRP head design.

The purpose of the development program is to provide data for the designers of the CRBRP head and rotating plugs. The leak rates of cover gas and its trace elements, including permeability, and the friction characteristics shall be measured for various parameters of the inflatable seal system in normal and off-normal reactor conditions.

This test plan describes the program to be conducted by Atomics International, in response to the Westinghouse Development Requirements Specification, DRS 32.06.

II. TECHNICAL APPROACH

The existing rotating inflatable seal test rig shown in Figure 1, and IVHM rotating plug seals (cross section in Figure 2) available from the IVHM Test Program will be used. Considerable performance data is available from the previous test. Parameters that were performance mapped during that test will not be repeated;^(1,2) but, where the range of values tested did not include CRBRP conditions, additional data points will be generated (e. g. , inflation pressure, speed, etc). Table 1 compares test conditions for the IVHM and the CRBRP seals.

The program consists of six phases:

- I. Parameter Testing (Beginning of Life)
- II. Life Cycle
- III. Parametric Testing (End of Design Life)
- IV. High Pressure and Pressure Transient and Tolerance Testing
- V. Test to Destruction
- VI. Testers' and Suppliers' Recommendations

A. PHASE I - PARAMETER TESTING (Beginning of Life)

The first task will be to select a lubricant(s) for the seals. The candidate lubricants will be evaluated on a lubricant test rig used for the general LMFBR Seal Development Program at AL. Dow Corning grease DC55M and Exxon grease WSX 8788 have been evaluated on the rig, and are the current lubricants recommended for elastomer seals. Other lubricants to be tested are spray-coated Teflon, oven-bonded Teflon, spray-coated MoS₂, and DC55M with 5% MoS₂ powder. Based on a comparison of these results, the inflatable seals will be given a lubrication treatment and started into testing.

FIGURE 1.
DYNAMIC SEAL TEST SYSTEM

FIGURE 2.

IVHM RRP DYNAMIC SEAL
REACTOR INSTALLATION

TABLE 1
COMPARISON OF IVHM TO CRBRP SEAL TEST CONDITIONS

Parameter	IVHM	CRBRP
Temperature	Room to 150°F	Same
Argon Pressure		
Reactor P_r Normal	0.5 psig	10 in. H_2O
Overpressure	25.0 psig	20 psia
Underpressure	3.0 psia	10.0 psia
Buffer Gas, R_b	1.0 psig	1 to 50 psig
Head Compartment, P_h	0.25 psig	Air Ambient*
Seal Inflation, P_i		
During Dwell	10 psig	25 psig
During Rotation	5 psig	TBD
Test Range	0 to 25 psig	TBD
Seal Speed, Nominal	2 fpm	15 fpm
Test Range		10 to 20 fpm
Life Travel	25,000 ft	80,000 ft
Duty Cycle	$\pm 180^\circ$	1) +1.5 rev 2) Dwell 1 min 3) -1.0 rev
Acceleration	- †	- †
Horizontal Runout	± 0.040 in.	± 0.040 in.
Vertical Runout		
Nominal	± 0.030 in.	§
Maintenance	-	Nominal +0.25 in.
To cause leakage	-	TBD
Lubrication	DC55M	TBD

*During the permeation run, a pressure of 0.25 psig will be maintained.

†Acceleration is not readily varied and is not instrumented for measurement on the AI test rig.

TBD = To Be Determined

§Variable within clearance of fixture cover

The following characteristics of the seal, at the beginning of its life, are measured:

- 1) The inflation pressure vs torque and leak rates, the leakage vs seal inflation pressures, and cover gas pressures up to 20 psia under static conditions
- 2) The leak rate and the torque required under nominal (15 ft/min) conditions for ~500 ft of travel
- 3) The leak rate and torque for higher (20 ft/min) and lower (10 ft/min) tangential velocities for ~500 ft of travel
- 4) The leak rate and torque under the condition simulating the loss of one of the two seals for ~500 ft
- 5) The radial and vertical runout on the test article will be as shown in Table 1 during all testing.

The nominal conditions consist of: (1) seal temperature of 150°F, (2) tangential velocity of 15 ft/min, (3) tangential acceleration will not be controlled, (4) seal inflation pressure and lubricant based on the results from Item 1, and (5) argon cover gas with trace elements representing radioactive gases, at 10 in. H₂O gauge unless otherwise specified.

The seal shall be rotated using the sequence: (1) 1-1/2 revolutions clockwise, (2) hold for ~1 min, (3) 1 revolution counterclockwise, (4) hold for ~1 min, and (5) continue the preceding sequence until the specified total travel is reached.

B. PHASE II - LIFE CYCLE

Using the nominal conditions arising from Phase I, and the preceding rotational sequence, the leak rate and torque measurements shall be performed over a total travel of 80,000 ft. A pause shall be made between each segment of 10,000-ft travel, to represent the stationary condition of the seals between refueling operations. Seal inflation pressure is to be ~25 psi at dwell to determine the effect on lubrication of long periods in static mode at higher inflation pressures.

C. PHASE III - PARAMETRIC TESTING (End of Design Life Cycle)

The tests in Phase I, exclusive of Item 2, shall be repeated immediately after the completion of Phase II, using the lubricant selected from Phase I. A measurement of the permeation rate of trace gases, H_2 and Kr, through the seal will be conducted, and compared to values measured at the end of the earlier tests during testing in support of the FFTF-IVHM. In addition, leak rate is to be measured under simulated maintenance conditions (i. e., stationary portion of test fixture raised 1/4 in.). After these tests, the seals will be inspected in the test facility.

D. PHASE IV - HIGH PRESSURE AND PRESSURE TRANSIENT TESTING AND TOLERANCE TESTING

Tests shall be run to determine the leak rate past the outer seal for buffer gas pressures up to 50 psi. The object of this test is to determine the sealing capability under off-normal conditions of a cover gas overpressure. The sealing properties are also desired for a cover gas underpressure, occurring in a scram, where the pressure drops from ~ 15 psia to ~ 10 psia. The transient behavior of the gas pressure will be specified, if it is determined to be important.

The blade-to-seal vertical separation will be increased, in steps, to a value of nominal +0.25 in., to determine the value at which excessive leakage occurs for various buffer gas pressures.

E. PHASE V - TEST TO DESTRUCTION

Based on results from the first four phases, some tests may be repeated or redesigned. After these tests are exhausted, the leak rate and torque tests shall continue under the nominal conditions used in Phase II until the end of life of the seal, or until 160,000 total cycles have been accumulated.

F. PHASE VI - TESTERS' AND SUPPLIERS' RECOMMENDATIONS

Based on the results of Phases I through V, and other available information, the following information will be defined:

- 1) Seal lubrication requirements defining the frequency, application technique, and type of lubricant to be used
- 2) Potential effect of long period (1 year) static condition between rotating motions, and of compression set within the specified lifetime
- 3) Irradiation effects, aging effects of the atmosphere and temperature, and recommended cleaning materials. In addition to testing, manufacturers' recommendations are to be solicited.

III. DESCRIPTION OF TEST

A. TEST ARTICLE

The inflatable seal, illustrated in Figure 3, is a full-scale seal, of the configuration and size specified for the IVHM-RRP rotating seal. The seal is manufactured by B. F. Goodrich, and is a composite structure, with a nylon-fabric-reinforced core, and an unreinforced wear or seal strip, vulcanized to the seal body. The elastomer used in both body and wear strip is a B. F. Goodrich "Hycar" nitrile* rubber, specially compounded for low-permeation dynamic service in a radiation environment.

The exact composition of this material is proprietary, and is coded by the B. F. Goodrich as Compound No. 139 PC-12. The principal constituent is known to be a copolymer of acrylonitrile (H_3C_3N) and butadiene (H_6C_4), with a nitrile content of 43 wt %.

The nylon reinforcing consists of two plies of woven fine-mesh cloth, ~5 mils thick. At the maximum inflation pressure (50 psig) of the seal, the fiber stress in this cloth is ~1200 psi, which produces ~1% strain in the chords. This strain is well within the 4% elastic limit of nylon fibers; therefore, no seal deformation will result from yielding of the nylon fabric.

The inflation stem incorporated in the seal design is a custom design, used to facilitate installation of the seal in both the seal test system and the IVHM.

For the IVHM design configuration and for this test system, the "Seal" will consist of a set of two inflatable seals in series as shown in Figure 2, where P_r is the reactor cover gas, P_i the seal inflation gas, P_b the inter seal buffer gas, and P_h the head compartment gas.

For normal operations, P_b is maintained slightly positive (1 psi) with respect to P_r , so that any leak of the purge gas will be forced to flow into the reactor, thereby insuring that the only cover gas which penetrates the first seal is that which permeates through it.

*Also referred to as Buna N, Perbuna, and NBR rubber

FIGURE 3.
INFLATABLE SEAL

[SCALE 2/1]

0

The installation of the seals in the glands will be accomplished using the Reference 3 procedure, except that lubrication will depend on the results of the lubrication evaluation in Phase I.

B. MEASUREMENTS

The primary performance parameters, permeation and drag, will be measured with a Varian Gas Chromatograph and a torque meter on the turntable, respectively. Figure 4 is a P&I diagram of the test setup, and Table 2 lists the measurements required for the test. Physical dimensions of the seals before and after the test, along with appearance, will also be used to gauge or predict performance.

C. FACILITIES, INSTRUMENTS, AND EQUIPMENT

The test will be conducted in an existing test setup in Bldg. 006 at Atomics International's Santa Susana Field Laboratories. A schematic of the turntable is shown in Figure 1.

FIGURE 4.

DYNAMIC SEAL TEST SYSTEM P&I
DIAGRAM

TABLE 2
INFLATABLE SEAL TEST RIG MEASUREMENT
ACCURACIES AND RANGES

Parameter	Accuracy		Range
Permeation	±20%		1-2000 ppm
Drag	±5%		0-100 lb/ft of seal
Buffer Gas Flow	±5%		0-5 scfd
Speed, Counter and Stop Watch	±10%		
Temperature			
Reading	±5°F		0-300°F
Control	±8°F		
	<u>Recorded</u>	<u>Manometer</u>	
Pressure			
P _b , Buffer	±0.01 psig	±0.03 in. Hg	±15 psi
P _r , Reactor	±0.01 psig	±0.03 in. Hg	±15 psi
P _i , Inflation	±0.05 psig	±0.03 in. Hg	±15 psi
R _h , Head Cavity	±0.01 psig	±0.03 in. Hg	±15 psi
As required	±0.10 psi		0-100 psi

Argon Trace Gases

Desired (%)	Derivation from Desired	Accuracy (%)
1	±500 ppm	±0.2
5	±0.25%	±0.1

IV. EXPECTED RESULTS

The leakage and drag is expected to be essentially the same as was measured on the IVHM seal, and reported in References 1 and 2. The speed and added travel is not expected to materially affect the results. After ~29,000 ft of travel, wear was not discernable after the test to IVHM conditions.

V. ALTERNATE TEST PLAN

If these state-of-the-art seals and materials do not satisfy the requirement, the test program must be redirected toward efforts which include development and testing of seals with special elastomer compounds or other lubrication schemes, such as devices to add lubricant or MoS_2 coating to the seal mating surfaces.

VI. DATA AND REPORTS

A. DATA HANDLING AND STORAGE

All measurements and data will be read from the appropriate instruments, and recorded in a Laboratory Notebook(s). In those cases where data are recorded on strip charts, pertinent data will be recorded in the Laboratory Notebooks, and charts dated and stored until the completion of the program (notebook writing should be of such clarity that a person unfamiliar with the program could follow the sequence of events). All data will be processed to provide permeation rate as a function of the test variable (i. e. , time, temperature, compression, etc), for inclusion in monthly, quarterly, and final reports.

After conclusion of the tests and the preparation of the final report for that phase, the Laboratory Notebook(s) will be returned to the library for storage.

B. REPORTS

Weekly summary reports will be provided to the AI-LMFBR Project Office.

Summaries of pertinent data will be prepared for the Monthly and Quarterly Progress Reports.

A Final Report will be prepared at the end of this phase of dynamic elastomer seal testing.

VII. SAFETY

No hazardous pressures, temperature, or materials will be used in these tests, with the exception of the hydrogen-traced argon supply for the simulated cover gas. The concentration of hydrogen in the argon will be <5%, so that inadvertent leakage of this source will provide no hazard.

The use of rotating machinery, including a gear belt speed-reducing system, does constitute a potential hazard; and all portions of this part of the drive system will be provided with protective covers and interlocks to preclude accidental motion during maintenance.

2

VIII. QUALITY ASSURANCE

A. ELASTOMER CERTIFICATION

Quality Assurance (Dept. 754) shall verify that all elastomer seals and material samples to be tested are certified to comply with RDT M 11-1T, Paragraphs 2.1, 2.2, 2.4, 2.5, 2.5.1, 2.5.2, 2.6, 2.6.2, and 2.6.3, and with RDT F 2-4T, October 1969, including Modification 1, February 1971, in its entirety (Note: RDT F 2-4T replaces RDT F 3-1T listed in Item 2.1 of RDT M 11-1T).

B. ELASTOMER TRACEABILITY

Quality Assurance (Dept. 754) shall verify that all elastomer material samples to be tested are identified as follows:

- 1) Base raw material manufacturer, trade name, code number, and recipe or recipe number, as applicable
- 2) Processor trade name, recipe or recipe number, and process or process number, as applicable.

Identification of elastomer samples shall be recorded in the Laboratory Notebook, and on the data sheets for each test.

C. ELASTOMER SAMPLE CONTROL

All elastomer material samples and seals, together with their certifications, shall be stored in a locked cabinet when not inserted in the test fixture. Cabinet key control shall be maintained by the Responsible Engineer and/or his supervision.

D. TEST SYSTEM MATERIALS

Test system materials, as required, shall be procured per applicable ASTM or RDT specifications.

E. FAILURE AND INCIDENT REPORTS

- 1) A Failure Report, describing any unexpected failure of the test samples or changes in test procedures, shall be prepared as required by EMP 5-19.
- 2) An Incident Report, describing any failure of the test apparatus or facility, shall be prepared as required by EMP 5-20.

F. TEST INSTRUMENTATION

All calibrated instruments shall be maintained in calibration throughout the test period. Calibrations shall be per Atomics International SOP K-68. This includes traceability to the National Bureau of Standards, or, in the absence of National Standards, to other generally recognized standards.

All other instruments shall be tagged as "Indication Only."

G. WITNESSES

Dept. 716-660 shall be responsible for notifying Quality Assurance Engineering (Dept. 754), the AI-FFTF Program Office, the AI-LMFBR Program Office, and personnel that Dept. 716-660 determines should be knowledgeable of and/or witness the actual testing.

Quality Assurance shall perform periodic surveillance during all test phases to assure compliance with the procedures, and to verify proper documentation of test conditions, data, deviations, and other potential information in the Laboratory Notebook. Performance of surveillances shall be entered in the Laboratory Notebook with the Inspector's stamp or signature.

IX. REFERENCES

- 1) "Annual Technical Progress Report - Sodium Technology and Cover Gas Seal Development Programs - Government Fiscal Year 1973," AI-AEC-13110 (September 15, 1973)
- 2) "Quarterly Technical Program Report - Sodium Technology and Cover Gas Seal Development Programs," AI-AEC-13113 (November 15, 1973)
- 3) "IVHM-RRP Dynamic Inflatable Seal, Installation of, Rev A," ST0620NA0087 (February 19, 1972)