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MASTER

I. PROJECT OBJECTIVES

DOE/SF/76026--T18

The objectives of the Cover Gas Seal Component Test Program are to develop and demonstrate the performance of commercial and custom-designed head region cavity seals for LMFBF reactors, to develop and evaluate advanced seal concepts capable of achieving improvement in radioactive gas containment and seal temperature-life capabilities, and to establish operational safety margins for head region seals for nominal and extraordinary LMFBF plant conditions.

During FY 1977, the CRBRP sodium dip seal configuration performance characteristics were determined and the seal demonstrated to meet system requirements. Current activities include verifying the acceptability of CRBRP head region inflatable elastomer seal manufacturers, developing the technology to improve static inflatable seal design, and determining the ultimate temperature capabilities of several elastomer seal materials. A new activity was initiated in June 1978 to design and analyze a flexing metal seal as an alternate concept to the inflatable elastomer seals.

II. MAJOR ACCOMPLISHMENTS DURING FISCAL YEAR 1978

All testing per Addendum 2 of DRS 32.06, plus additional tests to determine the effects of horizontal and vertical misalignments on cross-seal leakage, were completed on the first vendor CRBRP qualification seals supplied by Seal Master Corp., Kent, Ohio. Seal performance met test criteria for

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dynamic and breakaway drag values, but exceeded cross-seal leakage limits by a factor of 4. The leakage was reduced to within the allowable 1×10^{-5} scc/sec-cm- Atm ΔP by increasing the inflation pressure from the nominal 1.53×10^5 Pa (7.5 psig) to 2.05×10^5 Pa (15 psig). This was the original recommended static pressure for seals of the identical configuration as used in the FFTF-IVHM.

The seals were tested through 64,000M (210,000 ft) of travel, two 300 dwell-breakaway tests and periodically measured for static cross-seal leakage all at 52°C (125°F) under an argon inflation pressure of 1.53×10^5 Pa (7.5 psig). Seal dynamic drag varied between 167 and 633 N/m (10 -38 lb/ft) and breakaway drag was 1000 N/m (60 lb/ft) or less. Specification allowables were 835 N/m (50 lb/ft) and 2500 N/m (150 lb/ft) for the dynamic and breakaway drag. As noted above, cross-seal leakage at the nominal pressure exceeded the allowable by a factor of 4. Visual inspection of the post-test seals showed no signs of wear or other effects of testing. Post-test sectioning of the seals showed the wall thickness to be much heavier than anticipated, possibly not within drawing tolerances, and verified assumptions that the low drag and high leakage at nominal inflation pressures were due to excessive rigidity of the seals. A final test report, N707TR810018, was issued documenting the test.

The Presray seals were received and installed in the fixture. Inspection showed them to be of very thin wall construction, but with good surface finishes. Initial tests showed drag to be excessive and leakage across the small diameter seal was excessive. Inspection of the seals showed two areas of localized separation of a thin, .005 cm (.002 in.) elastomer coating on the wear strip which was identified by the supplier as a post-cure applied "cosmetic" film. Testing of the seal through 16,000 m (52,000 ft.) of travel resulted in a stabilized drag of 1200 N/m (72 lb/ft), considerably above the allowable 835 N/m (50 lb/ft). A second inspection of the seals showed the separation had increased in size and in depth to $\sim .075$ cm (0.03 in.) in one spot. Testing has been suspended until resolution of the problem is reached.

Four each: (1) stainless steel mesh reinforced, and (2) aluminum foil gas permeation barrier, containing static inflatable elastomer test bladders, were received. All test bladders were of marginal quality with numerous wrinkles across the sealing face, but were pressure tight and inflated to an acceptable configuration when pressurized. The wrinkles were due

principally to stiffness of the steel mesh and aluminum foil. A test plan was prepared and gas leakage tests were conducted on one bladder of each type through 2000 hrs. at 121°C (250°F). A computer program has been written and analysis of the data is in progress.

A test plan was prepared and the first thermal degradation test, on nitrile seals, was initiated. Cross-seal gas leakage rates were made at 66°C (150°F) to verify consistency with previous tests and testing at 121 and 149°C (250 and 300°F) is establishing material capabilities.

A new task, to design, analyze, fabricate, and test an alternate seal concept was initiated in late June. The seal design is based on a pre-loaded metal spring seal with a solid cross-section elastomer-to-metal seal. Concepts based on free supported and fixed cantilevered rings are being evaluated.

III. PROGRESS DURING THE REPORT PERIOD

A. CRBRP INFLATABLE SEAL VENDOR QUALIFICATION

The inflatable seals manufactured by Presray, Inc. were delivered to AI on April 17 after having been inspected and accepted by Westinghouse ARD personnel. The seals were inspected by AI engineering and were photographed to show typical construction and areas with minor defects including surface roughness and mold flash. Both seals were judged to be of good quality but are very pliable and quite thin-walled. Actual wall thickness cannot be measured until testing is completed and the seals are sectioned.

Prior to installation of the Presray seals, the Seal Master seals were removed from the test fixture and sectioned. The seal wall construction was considerably heavier than anticipated and possibly not within drawing tolerances. Figure 1 illustrates the measured comparative cross-sections of the original B. F. Goodrich and Seal Master seals and includes an estimated thickness of the Presray seal based on handling and flexure of the seals. Sidewall tolerances of the Goodrich seal were .33/.18 cm (.13/.07 in.) and it is understood that nominal dimensions of the Westinghouse drawing used to procure the Seal Master and Presray seals were: sidewall 0.25 cm (0.1 in), base 0.53 cm (0.21 in), and wear strip 0.56 cm (0.22 in).

The heavier wall construction of the Seal Master seal resulted in lower drag and greater leakage as compared to the Goodrich seal under the nominal inflation pressure of 1.53×10^5 Pa (7.5 psig). Under the nominal conditions,

COMPARISON OF INFLATABLE SEAL CROSS-SECTIONS

Figure 1.

* estimated values, actual dimensions to be made at conclusion of tests.

dynamic drag for the Seal Master and Goodrich seals stabilized around 300 and 500 N/m (18 and 30 lb/ft), respectively and leakage across the Seal Master seal was ~ 4 times that of the Goodrich seal. Increasing the inflation pressure of the Seal Master seal to 2.05×10^5 Pa (15.0 psig) lowered the leakage to acceptable levels equivalent to that of the Goodrich seal.

At the respective pressures, both seals functioned properly and similar construction would have produced similar results. Results of tests on the Seal Master seal are discussed in AI-DOE-13221. As discussed below, the thin wall construction of the Presray seals resulted in a corresponding increase in seal drag as compared to the original Goodrich cross-section.

The Presray seals were installed per AI Specification ST0620NA0095 and the Chemlok 304 adhesive allowed to cure for two days. Both seals were measured for seal groove height and vertical runout as a function of inflation pressure. At 1.21×10^5 Pa (3 psig) the nominal seal height, referenced to 0 at 1.01×10^5 Pa (0 psig) was 0.74 cm (0.29 in) with two or three locations on each seal, probably at fabric lap joints, at a minimum height of 0.28 cm (0.11 in). With a maximum vertical gap of 0.15 cm (0.06 in) and a nominal inflation pressure of 1.53×10^5 Pa (7.5 psig) both blades would fully engage the seals and no gross leakage should occur.

The blade assembly and test fixture lid were installed with the nominal 0.30 cm (0.12 in) vertical and horizontal runout and seal temperatures stabilized at 52°C (125°F). Seal rotation was initiated at 1 cm/sec (2 ft/min) with the seals deflated. Seal inflation pressure was increased in steps to the nominal 1.53×10^5 Pa (7.5 psig) pressure and seal speed increased to the nominal 7.6 cm/s (15 ft/min). Table I shows the seal drag increase as a function of the pressure and seal speed increases. At nominal conditions the 883 N/m (53 lb/ft) exceeded the specification allowable of 835 N/m (50 lb/ft).

TABLE I
Seal Drag During Initial Startup

Seal Speed cm/s (ft/sec)	Pressure Pa (psig)		Seal Drag N/m (lb/ft)	
	Inflation	Buffer		
1.0 (2.1)	1.01×10^5 (0)	1.01×10^5 (0)	0	(0)
	1.22×10^5 (3)		367	(22)
	1.36×10^5 (5)		533	(32)
1.0 (2)	1.36×10^5 (5)	1.01×10^5 (0)	766	(46)
7.6 (15)	1.53×10^5 (7.5)	1.08×10^5 (1)	885	(53)

An initial static cross-seal leakage test was conducted under nominal conditions of 1.53×10^5 Pa (7.5 psig) inflation and 1.08×10^5 (1 psig) buffer cavity pressure resulting in a leak rate of 9×10^{-5} scc/sec-cm-Atm Δ P. As this was in excess of the specification limit, it was decided to operate the seal to determine any effects of "wear in."

Automatic rotation was initiated and dynamic seal drag increased to 1170 N/m (70 lb/ft) during a 7 hr. sequence. Based on the thin wall construction of the seal, drag was anticipated to be somewhat higher than with previous seals, but the steady increase in drag was of some concern and leakage was greater than expected.

The fixture lid was removed and inspection of the seals revealed two areas ~ 15 cm (6 in) apart on the wear strip of the small diameter seal, adjacent to the inflation stem location, with localized separation of a thin elastomer film $\sim .005$ cm (.002 in). Figures 2 and 3 illustrate these areas. The Westinghouse cognizant engineer was informed and in turn contacted the supplier who acknowledged that a thin "cosmetic" film had been applied to the seals after the initial cure cycle. The seals were then reinstalled in the mold and a second cure cycle performed. It was apparent that the separations occurred at this interface. It was agreed between AI and Westinghouse engineering that testing should be resumed as the probability of seal repair was remote.

Nominal test conditions were reestablished and static cross-seal leakage rates for each seal were measured. Leakage across the outer seal was less than the allowable 1×10^{-5} scc/sec-cm-Atm Δ P at inflation pressures of 1.35×10^5 Pa (5 psig) or greater while leakage across the inner seal was considerably in excess of the allowable at the nominal 1.53×10^5 Pa (7.5 psig) pressure. The seals were then operated through the first planned dynamic drag sequence of 16,000 m (52,000 ft.) of travel using the standard programmed cw, ccw oscillating test mode. Dynamic drag showed a steady increase throughout the first half of the sequence varying from an initial 933 N/m (56 lb/ft) to a final stabilized drag of 1200 ± 80 N/m (72 ± 5 lb/ft). The excessive drag, as compared to previous seals and the specification allowable of 835 N/m (50 lb/ft) was due to the thin wall construction of the seals. A short test measuring drag of each seal independently showed drag to be approximately the same. Figure 4 shows a summary of drag for the Presray seals and for the previously tested Goodrich and Seal Master seals.

9283-60

Area of Inner Seal Wear Separation
(15 cm ccw from inflation stem, viewed from the top)

Figure 2.

Area of Inner Seal Wear Strip Separation
(Adjacent to Inflation Stem)

9283-56

Figure 3.

The fixture lid was removed and reinspection of the seals showed that the localized separation on the small diameter seal had increased and that the two areas of separation had progressed towards each other and had increased in depth to ~.075 cm (.030 in) at one end. Figure 5 shows the overall area and Figure 6 illustrates details of both ends of the separated section. Westinghouse and Presray were informed of the seal condition and planned testing has been suspended until the cause and any resolution can be agreed upon. The separated elastomer, thin at both extremes and heavy toward the center, appears to be covering a low section in the seal wear strip. Presray stated they made no repairs to either seal except for application of the thin "cosmetic" coating. The West Coast representative of Presray visited AI on June 27 and in discussions with AI engineering, it was concluded that the elastomer wash applied as a cosmetic coating probably collected in a low spot on the seal wear strip prior to curing and consequently formed a localized heavy section. There is no way of knowing whether the failed section is the only heavy area on the seals without sectioning them.

The use of multiple cure cycles is not a standard procedure and repair of seals has not been permitted without knowledge of the buyer. While Presray did not regard the cosmetic coating as a repair, under the AI definition, any post-cure modification or addition to the basic seal carcass would constitute a repair. Specific wording of the Westinghouse procurement specification would verify whether or not the actions of Presray were allowable.

While the outer seal has met specification leakage requirements and seal drag can be reduced to acceptable limits by reducing the inflation pressure, failure of the inner seal would appear to be necessary grounds for disqualification of Presray as a seal supplier. As there are insufficient time and funds to test new uncoated seals, resumption of testing will be based on resolution of action on the current seals following discussions with Westinghouse and Presray.

B. STATIC INFLATABLE SEAL DEVELOPMENT

Seal permeation tests were concluded after a total of 2000 hours at 121°C (250°F) on both the steel mesh and aluminum foil containing test bladders. Validity of raw data has been verified, but due to the problems associated with the CRBRP inflatable seals, analyses of the leakage data has not been completed. A computer program has been written and analysis is in progress.

COMPARISON OF DYNAMIC SEAL DRAG FIGURE 4

- GOODRICH
- ▲ SEAL MASTER
- PRESRAY

9283-60

Area of Inner Seal Separation
Figure 5.

9283-59

9283-58

Details of Separated Inner Seal Sections
Figure 6.

C. HIGH TEMPERATURE SEAL DEGRADATION

Cross-seal leakage tests are in progress on two sets of Parker Seal N741 nitrile O-rings to determine the relationship between leakage and temperature in excess of nominal use conditions. An initial 500 hour test at 66°C (150°F) established H₂ leakage to be 30x10⁻⁸ scc/sec-in of seal - Atm ΔP, close to the 49x10⁻⁸ value obtained in previous tests (AI-AEC-13146) on the same material. Initial checks on rates at 121°C (250°F) showed stabilization at ~4 times the 66°C values. Tests are currently in progress at 149°C (250°F) and leakage rates are being calculated.

Duplicate tests are being set up with Parker Seal E692 EPDM O-ring seals. Testing on these seals and similar silicone seals will be initiated in July.

D. ALTERNATE SEAL CONCEPTS

In late June a new activity was initiated to design, fabricate, and test a rotating seal based on the concept of a flexible metal ring with a solid elastomer-metal sealing interface. The proposed designs are intended to be alternate concepts to the existing rotating inflatable seals. Two designs, one a supported ring and the second a cantilevered ring are the basis for the design effort and are illustrated in Figures 7 and 8. Both will be designed to operate under existing CRBRP drag and cross-seal leakage requirements and, if possible, will incorporate the function of the margin seal to contain a 20.7x10⁵ Pa (300 psi) pressure surge lasting 1000 seconds. Initial effort is being concentrated on sizing ring cross-sections as a function of seal diameter, 1.8 to 9.1 m (6 to 30 ft.), load, stress, and vertical runout.

III. IMPACT ON LMFBR PROGRAMS

Elastomer and sodium dip seals developed under this program provide the primary radioactive gas containment barrier for LMFBR systems. Advances in sealing efficiencies and seal thermal capabilities will increase reactor safety margins and relax thermal restraints in seal containing machines. Verification of non-inflatable rotating seal concepts will permit use of seals with standard fabrication techniques and minimize reliance on specialized processes.

SUPPORTED RING
FIGURE 7

V. NEXT REPORT PERIOD ACTIVITIES

Disposition of the Presray seal will be made and testing completed or terminated as required. A final test report comparing quality and performance of the Presray and Seal Master seals will be made.

Pressure cycling tests will be completed on the steel mesh and aluminum foil containing inflatable seal test bladders and a final report will be issued. Thermal degradation studies will be completed on the nitrile, EPDM, and silicone seals and a final report issued.

Designs will be finalized on a supported and cantilevered flexing metal ring seal. Drawings will be prepared and quotations obtained for fabrication cost and delivery.