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I. PROJECT OBJECTIVES

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 LMFBFR 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 LMFBFR plant conditions.

During FY 1979, the major effort has been directed toward designing and analyzing concepts for flexing metal dynamic seals as alternate concepts to inflatable elastomer seals. In June, the program was redirected to concentrate on improving and simplifying fabrication techniques and designs of inflatable elastomer seals.

II. TECHNICAL PROGRESS DURING FISCAL YEAR 1979

Dynamic inflatable seals were incorporated into the design of the Fast Flux Test Facility In-vessel Handling Machine (FFTF-IVHM) by ESG in 1970 and that same basic design was subsequently included in the Clinch River Breeder Reactor (CRBR) rotating plug design. Following a decision by the original elastomer seal supplier not to continue fabrication of these custom products, a vendor qualification program was successfully conducted in FY 1978 (ESG-DOE-13248) with two companies; Presray Inc., Pawling, N.Y., and Seal Master Corp., Kent, Ohio, providing test seals.

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A. Flexible Metal Seal Concepts

In June, 1978, a new activity was initiated to design and develop a viable alternate concept to the inflatable seals. While the inflatable seals provided a reliable containment barrier to radioactive cover gas, the concept has several deficiencies, particularly;

1. Fabrication techniques are highly specialized with a limited number of suppliers (~three in the U.S.).
2. The inflatable seal is not designed to contain reactor pressure surges and requires a backup seal to contain postulated accident condition pressure spikes.
3. The seals represent the most permeable radioactive gas containment barrier in the reactor perimeter.
4. Temperature of the reactor head is limited by the inflatable seals.

A number of alternate seal concepts were considered with the principal goals of:

1. Eliminating inflatable seals.
2. Avoiding new concepts based on proprietary concepts or requiring single source processes.
3. Utilizing standard fabrication techniques.
4. Retaining the vertical and horizontal compliance of inflatable seals.

Among the concepts considered, three alternate designs, all based on the deflection of a pre-loaded metal ring, were selected as the most viable and are described below. For reference, Figure 1 illustrates a typical inflatable seal installation.

1. Supported Ring Concept

The supported ring, Figure 2, consisted of two flexible metal rings arranged as mirror images. Each ring had a static O-ring seal at the fixed pivot point and an extruded elastomer ring at the dynamic interface. The recessed groove at the dynamic interface was designed to act as a lubricant reservoir. The design also incorporated a buffer gas cavity which when pressurized assisted the seal and utilized the

INFLATABLE ELASTOMER SEAL

FIG. 1

Figure 2 Supported Ring

outer seal ring as a pressure surge seal. The key area of design was to select the flexible ring thickness to provide the necessary vertical compliance with an acceptable resultant drag on the dynamic interface.

2. Cantilevered Ring Concept

Figure 3 illustrates a similar concept except the ring edge opposite the seal blade is fixed; i.e. welded to the retainer. This eliminates the static O-ring seal interface and one potential gas leak-path. Both seals are assisted by the buffer cavity, and the outer seal is effective against an over pressure surge. This concept is the simplest of the three and was considered to be the least expensive to fabricate.

3. Compound Cantilevered Ring Concept

Figure 4 illustrates a compound cantilevered ring which by proper selection of ring dimensions utilizes the buffer pressure to assist sealing under nominal conditions and utilizes both seals to prevent leakage in the event of a pressure surge. Under normal conditions, the buffer pressure maintains a seal due to the larger pressure area of the upper blade. With a high pressure surge, the longer blade is deflected to press against the buffer cavity roof and simultaneously the shorter blade is pressed against the elastomer pad. As with Concept 2, this high pressure surge would result in a permanent deformation of the seal and require replacement.

In the initial analysis, it was concluded that the compounded cantilevered concept was impractical to fabricate because of the thin rings and large diameters. A preliminary design and analysis was then initiated on the supported and cantilevered ring concepts with the following ultimate objectives.

1. To produce engineering drawings of the two concepts and obtain fabrication quotations for seal assemblies of 6, 21 and 33 ft. nominal diameters (sizes required for proposed PLBR concepts).
2. To fabricate test assemblies of the 6 ft. diameter seal concepts and conduct proof of principal and performance qualification tests using the existing rotating seal test facility (previously used in the inflatable seal qualification tests).

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Figure 3 Cantilevered Ring

COMPOUND CANTILEVERED RING

FIG. 4

A preliminary design review resulted in several changes to simplify fabrication and improve seal reliability. The resulting cross-sections for the 6 ft. diameter seals are shown in Figures 5 and 6 as they would be installed in the modified seal test fixture. A series of engineering drawings, identified as N707000059-N707000072, were prepared detailing the 6, 21, and 33 ft. dia. reactor seals of both concepts. A separate drawing, N707000075, detailing the trapezoidal shaped dynamic elastomer seal required for all seal rings was completed. Test fixture modifications necessary to test the 6 ft. dia. seals were incorporated in revisions of drawings EX-N707800006 and EX-N707800008.

A request for quotation (RFQ) was issued for:

1. Modification of the seal test facility.
2. Fabrication of a 6 ft. dia. supported ring seal assembly (for proof of principal test).
3. Fabrication of a 6 ft. dia. cantilevered ring seal assembly (for proof of principal test).
4. Verification of the ability and willingness to fabricate 21 and 33 ft. dia. reactor seal assemblies of either concept with cost estimates.

A key condition of the RFQ was that in order to be considered for fabrication of the test seals, the bidder must meet item 4 above. This condition was included in order to verify that there were manufacturers who had both the capacity and the interest in fabricating large diameter, small cross-section ring assemblies, which because of their flexibility and tight O-ring tolerances would be difficult to machine. A preliminary survey of potential fabricators was conducted and the RFQ was sent to five suppliers who fabricate large diameter, close tolerance rings or structures. Four of the five "no bid" the package and the RFQ was reissued to eight additional manufacturers. Included were three major fabricators of large diameter bearings; Rotek, Inc., FAG Bearing Corp., and Messinger Bearing Corp., all of whom no-bid. Rotek and FAG have facilities of the required size in W. Germany, but in order to ship the 33 ft. dia. rings it was necessary to segment them which would have necessitated on-site welding of the segments and localized machining, neither of which were considered practical or desirable. A subsequent bid by Allis Chalmers, York, Penn., also stipulated that shipment would necessitate segmented seals.

Figure 5 Supported Ring Seal - 6-ft Diameter Test Configuration

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Figure 6 - Cantilevered Ring Seal - 6-ft Diameter Test Configuration

HITCO, Los Angeles, Calif., the only fabricator to bid the total package, bid ~\$30,000 for the test seals and ~\$150,000 for each set of 21 and 33 ft. dia. reactor seals. Chicago Bridge and Iron-Nuclear (CB&I-N). Memphis, Tenn., also bid ~\$150,000 for the reactor seals, but declined to bid the test seals. CB&I-N is currently the prime contractor on the CRBRP reactor vessel. Newport News Shipbuilding Corp., later indicated they had the capability of fabricating 30 ft. dia. rings and were interested in entering the reactor vessel construction business. They indicated they would be interested in fabricating seal rings as a part of a larger reactor vessel contract. HITCO, CB&I-N, and Newport News all are located adjacent to dock facilities and stated that shipment of the large diameter seal rings was predecated on the availability of a water route and dock side facilities at the proposed reactor site.

A review of the preliminary stress analysis by the ESG stress department resulted in a detailed analysis of the designs using finite element techniques. The analysis showed that the previous cantilevered ring calculations overestimated the ring thickness and that revised thicknesses were too thin to be practical without increasing the ring width beyond design limits of ~3 in. This limit was imposed to preclude increasing the riser assembly cross-section beyond that established for the reference elastomeric inflatable seals in the ESG design of the EPRI LMFBR Pool reactor.

The supported ring drawings were modified to incorporate the cross-sections generated by the finite elements computer analysis as shown in Figures 7, 8 and 9. The primary change in the modified cross-sections were the elimination of the support lip on the underside of the rings at the static seal interface which contributed significantly to the rigidity of the beams.

A summary of the bid response activity was presented to the ESG Program Office which in turn forwarded a letter to the DOE Program Office recommending that the Alternate Seal Concepts Task be discontinued. The original premise of the concept was to replace the inflatable elastomer head region seals with a flexible metal seal system having several inherent advantages including:

1. Fabricability by standard non-specialized techniques and suppliers required for the inflatable seals.
2. Lower fabrication costs.

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Figure 7. Modified Seal Cross-Section-Finite Element Analysis - 1.8 m (6 ft) Diameter

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Figure -8 Modified Seal Cross-Section-Finite Element Analysis - 6.4 m (21 ft) Diameter

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Figure 9. Modified Seal Cross-Section-Finite Element Analysis - 10 m (33 ft) Diameter

3. Elimination of the necessity of a margin seal.
4. Improved reliability and temperature capabilities.

Based on an appraisal of the completed design, stress analysis, and supplier fabrication quotation activities, it was concluded that the flexible metal seal did not provide all the anticipated advantages. The combination of small cross-section and large diameter for the full-size reactor seals (maximum diameters of 10 m or 33 ft) severely limited the number of potential fabricators. As previously noted, only two suppliers bid on fabrication of the full-size seals with quoted prices equal to or greater than similar sized elastomer seals. As there are currently no plans to incorporate the design in proposed reactor designs, it was concluded that improvement of the inflatable seal concepts would be more beneficial and cost effective.

It was recommended to DOE that two new activities be initiated:

- 1) to instigate a study to determine whether or not an extruded elastomer seal with a vulcanized-spliced joint would meet CRBRP/LMFBR dynamic inflatable performance requirements as a replacement for the current molded seal, and
- 2) to design, fabricate, and test an ESG concept of a non-bladder elastomer inflatable seal. Following DOE concurrence, both activities were initiated in mid-June.

A report ESG-DOE-13299, "LMFBR Head Region Flexible Metal Seal Concepts," was written detailing the analysis, design, and fabrication bid aspects of the flexible metal seal task.

B. Extruded Inflatable Seal Test

Using the proven dynamic inflatable seal design of Figure 10, a task was initiated to determine if a seal of the same quality could be fabricated using an extrusion process as opposed to the current molding process. By using an extruded seal with secondary cure vulcanized joints it was expected that 1) the cost of fabricating the seals would be decreased, and 2) a larger number of fabricators would be capable of supplying the seals.

Based on the existing seal design and the extrusion fabrication process, a drawing was prepared detailing 6 ft. diameter test seals and 24 in. long splice-joint test specimens. The seals will be tested to CRBRP performance criteria and the tensile specimens will be used to determine time-temperature effects on joint strength.

A survey of qualified rubber extrudes was conducted and a RFQ issued for sets of test seals and tensile specimens. Two bids were received and a purchase order issued to Seal Master Corp. to fabricate the seals. Delivery is promised for mid-December, 1979.

C. Non-Bladder Inflatable Seal

A new seal design, based on an ESG concept which incorporated a solid extruded elastomer riser held in a metal retaining ring was designed. The seal concept, illustrated in Figure 11, eliminates the need for the elastomer bladder while retaining the vertical and horizontal compliance attributes of the current seal design (Ref. Fig. 10). A 6 ft. diameter test seal was designed for a proof of principal test and RFQ's issued for fabrication of 1) the extruded elastomer seals and 2) the metal retaining ring. Bids have been received for the retaining ring and are due at the end of October for the elastomer seal. Testing will be conducted in the existing inflatable seal test facility and results will be compared against those of the previously tested molded seals and the extruded bladder seals to be tested in FY 1980.

III. ACTIVITY DURING THE REPORT PERIOD

A. Flexible Metal Seal Concepts

This activity was discontinued during the third quarter of this fiscal year. A summary report, ESG-DOE-13299, "LMFBR Head Region Flexible Metal Seal Concepts", was written and is in the progress of publication.

B. Extruded Inflatable Seal Test

A drawing, N707000077, was prepared detailing the existing seal configuration based on extrusion techniques and options with and without fabric reinforcement. Also included on the drawing were seal segments, ~24 in. long, with post-extrusion cured splice joints duplicating those of

Figure 10 CRBRP Inflatable Seal Cross Section

Pneumatic Seal

FIGURE 11

the full seal joints. These specimens will be subjected to thermal soaks at 150°F for up to one year and pulled to failure to establish joint strength. Tests will also include control specimens from previously tested molded seals.

Based on the vendor survey conducted last quarter to identify firms capable of extruding elastomer products with integral woven fabric reinforcement, a list of potential suppliers were identified and an RFQ based on ESG drawing N707000077 was issued to ten firms. Responses to the RFQ included five no-bids, three no responses, and two bids from Seal Master Corp. and Presray, Inc., both previous suppliers of the original molded seals. The low bid was within the \$15,000 estimated and a purchase order was placed in mid-September with Seal Master Corp. to fabricate:

1. Two sets of 6 ft. dia. extruded fabric reinforced seals.
2. Two sets of 6 ft. dia. extruded seals without fabric reinforcement.
3. 24 test specimens each of fabric reinforced and non-reinforced elastomer for joint strength tests.
4. ASTM test slabs of the seal elastomer for gas permeation tests.

Delivery date of the full order was estimated for 12-12-79. A single set of molded seals provided by the same supplier in FY 1978 cost — \$9,000.

C. Pneumatic Seal

The non-bladder inflatable seal design was conceived at ESG as a replacement for existing static bladder containing inflatable seals. The concept illustrated in Figure 11, was further adapted for use as a dynamic seal by incorporating the elastomer-strike blade interface proven in the CRBRP dynamic inflatable seal tests (Ref. 2). The concept eliminates the bladder required for conventional inflatable seals and replaces it with a solid extruded cross-section which is simpler to manufacture and eliminates the need for highly specialized suppliers.

To evaluate the concept, a 6 ft. diameter test article was designed for installation in the existing inflatable seal test facility previously used to performance qualify the FFTF-IVHM and CRBRP dynamic inflatable seals. The seal design will permit testing in both static and dynamic mode and permit comparison of results against previously test molded seals and extruded seal of Task B above.

Two drawings, N707000078 and N707000079, were prepared detailing the retaining ring and the extruded elastomer seal. A RFQ was issued and a low bid of \$4500 was received for fabricating the retainer ring. A purchase order was prepared and will be issued early in FY 1980 with a delivery schedule of four weeks. The extruded seal RFQ was issued in late September to the manufacturers identified in the vendor survey conducted for the extruded inflatable seal task (Task B). Close of bids was set for the last week in October with seal delivery in December, 1979.

D. Seal Development History

A report, ESG-DOE-13298, "LMFBR Inflatable Elastomer Seals, Development and Test History", was prepared summarizing the efforts at ESG related to the development and testing of static and dynamic inflatable elastomer seals since 1968.

IV. IMPACT ON LMFBR PROGRAMS

Elastomer and sodium dip seals developed under this program provide the primary radioactive gas containment barrier for existing and proposed LMFBR systems. Improvement in seal construction techniques are planned to reduce the highly specialized skills required for molded elastomer seal fabrication and increase the number of potential suppliers. Proof testing of the non-bladder inflatable seal concept will provide a viable alternative to the bladder containing seal and further simplify seal design and fabrication.

V. NEXT PERIOD ACTIVITIES

A test procedure will be prepared for the extruded inflatable seals and the test seals delivered during mid-December. The test apparatus will be checked-out and prepared for performance tests.

Bids from the non-bladder extruded seal RFQ will be received, evaluated, and a supplier selected. Purchase orders will be placed for fabrication of the extruded seals and the seal retainer ring.

References

1. P. H. Horton, "LMFBR Head Region Flexible Metal Seal Concepts", ESG-DOE-13299 (October, 1979).
2. P. H. Horton, "LMFBR Inflatable Elastomeric Seals, Development and Test History", ESG-DOE-13298 (October, 1979).