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COVER-GAS-SEAL COMPONENT DEVELOPMENT

DOCUMENT TITLE

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IMPROVEMENT

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ABSTRACT

This report documents the 1) radial compliance and 2) low friction coating tests conducted on the CRBRP Rotating Plug Inflatable Seals per test plan N707TR810014. Test results show that narrowing the seal blade from 0.25 to 0.12 in. will effectively reduce dynamic drag from 30 to 20 lb/ft under nominal conditions and will increase seal radial compliance from 0.12 to 0.30 in. without an unacceptable rise in dynamic drag.

Tests also demonstrated that application of a teflon coating to the seal wear surface reduced breakaway drag by 25% based on results of comparison dwells.

It is recommended that follow on tests be run with the narrow blade and coated seals combination to verify the improved performance in anticipation of recommending

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their incorporation into the CRBRP and future designs.

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I. INTRODUCTION

The CRBRP dynamic inflatable seal has undergone two qualification test series; initially under the original FFTF/IVHM seal development Ref. 1) task and then under the extended CRBRP seal qualification task (Ref. 2 and 3) per DRS 32.06 Under these programs the seals' performance, capabilities, and limitations were fully characterized, including:

1. Static and Dynamic Drag, as a function of:
 - a) Seal inflation pressure
 - b) Temperature
 - c) Rotational velocity
 - d) Radial seal-to-seal track misalignment
 - e) Amount and type of lubricant
2. Static and Dynamic Cross-Seal Leakage, as a function of:
 - a) Inflation pressure
 - b) Buffer cavity pressure
 - c) Radial misalignment
 - e) Velocity
3. Post-Static Dwell Breakaway Drag, as a function of:
 - a) Dwell time
 - b) Inflation pressure
 - c) Buffer cavity pressure
 - d) Velocity
 - e) Lubrication

Based on the test information obtained and CRBRP design and fabrication limitations, two areas of improvement were identified.

These are 1) increasing the radial compliance, and 2) decreasing the breakaway drag of the seals. The CRBRP tests demonstrated that with the reference seal cross-section, Figure 1, using a 0.25 inch wide striker blade, and the current test hardware, a maximum radial misalignment of 0.25 inch T.I.R. could be obtained. At this point the seal shoulder was forced against the wall of the seal gland by the offset blade. The drag forces were shown to be unaffected by misalignments up to 0.10 inch T.I.R., but rose at an increasing rate with greater misalignments. Two approaches of providing greater misalignment capability with the existing elastomer seal were identified. These are 1) to reduce the striker blade width, and 2) to reduce the seal gland shoulder height.

For these tests it was decided to reduce the blade width to 0.12 inch which would theoretically increase the radial compliance to 0.38 inch T.I.R. without increasing the drag. The potential problems were an increase in drag due to an increased unit loading on the seal blade (due to the reduction in blade width) and an increase in seal wear rate.

Reducing the seal gland height, which would allow the seal wall to deflect horizontally, was rejected due to greater cost for fixture modification. Also, the top third of the seal side wall would be unsupported and could possibly balloon on inflation, increasing the stress in the side walls and reducing the contact pressure on the blade, resulting in cross seal gas leakage.

II. OBJECTIVES

The objectives of these tests were to demonstrate an improvement in performance for the CRBRP rotating plug seal by: 1) increasing the radial compliance, and 2) reducing the breakaway and nominal dynamic

drag of the seal. Specifically, one test demonstrated the ability of the seal to accept radial misalignments between the seal and seal track approaching 0.38 inch T.I.R. (total indicated runout) due to a reduction in blade width. A secondary objective of this test was to assure that the modified blade would not result in an increase in seal drag or cross-seal gas leakage. The second test demonstrated that applying a low-friction polymer coating to the elastomer seal will reduce breakaway drag to acceptable levels without loss of the coating.

III. TEST ARTICLE DESCRIPTION

The test article consists of two concentric inflatable elastomer seals (nominal diameters of 70.62 and 73.62 in.) and the mating seal blade track assembly. The seals were manufactured by B.F. Goodrich (B.F.G. Drawings 3C1322-1 and -2), using a proprietary acrylonitrile elastomer (B.F.G. Recipe No. 139-PC-12) with a nylon reinforcing fabric in the seal body. Figure 1 illustrates the cross-section of the standard seal/blade assembly used as reference configuration for the FFTF-IVHM closure head seal and the CRBRP rotating plug seals.

The narrow blade track assembly, Figure 2, is identical to the standard track used in previous tests, except the striker blades are 0.12 in. wide as opposed to the nominal 0.25 in. blade. Copies of the purchase order and vendor compliance report are in Appendix A.

Several low friction coatings were evaluated and a TF-R-6 spray-on teflon, manufactured by Tetrafluor Division, Royal Industries, was selected as meeting the low-friction requirements while having cure parameters (1/2 hr at 300 degrees F) which would not damage the elastomer seals. The "as supplied" coating was a TF-R-5 material as the -6 coating cracked and spalled on test specimens. The differences in the two materials are very slight. Supplier certification sheets are presented in Appendix A.

NOTES: UNLESS OTHERWISE SPECIFIED ON THIS DRAWING

1. DRAWING INTERPRETATION PER ST018NA0019
- ① 2. WELD PER AWS D11.1REV1-7% PENETRANT INSPECT ROOT
PASS PER AWS D11.1M-2.18.15 RADIOGRAPH COMPLETED WELD
PER AWS D11.1 PART B SECT 6.0.18.15 PENETRANT INSPECT
MACHINED SURFACE OF WELD PER AWS D11.1REV1-7% M-2.18.15
3. CLEAN PER ST018NA0020

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N70700005-01	SEAL TRACK	B04 S/N DATE 68A	A240 OR A479	(1)
QTY PLUG	PART OF IDENTIFYING NO.	HOW CALCULATED BY DIVISION	MATERIAL	DRAWING INFORMATION, SPECIFICATIONS, ETC.
PARTS LIST				
		Rockwell International Corporation Atomic's International Division		
		IN OF BLDG UNIT	MODIFIED SEAL TRACK - CRBPB ROTATING SEAL TEST	
		DATE		
		BY		
		CHECKED		
-01 N70700005 TEST	SUP	DATE	E 09974 N707000056	
APPROVATION	REMARKS	DATE	INITIALS	

A copy of the B.F. Goodrich physical properties report, 74-05-025, for the elastomer seals is included in the appendix of references 2 and 3

IV TEST PROCEDURE

A. EXCEPTIONS

Tests were conducted per AI Development Test Procedure N707DTP810016 with the following exceptions.

1. Item VII C.I.

The narrow blade track installation required that the vertical tilt be in the directions of stations 4-10 due to the direction of the mounting slots. Test data was unaffected by this change.

2. Item VII C.5

The 0.50 in. T.I.R. test was deleted to prevent damage to the seals. The 0.25 in. T.I.R. test was deleted as sufficient data was obtained without it. Ambient tests of Table II were deleted for the majority of tests as seal performance characteristics were sufficiently established without them.

3. Item VII D.6.

The dwell was reduced to 300 hours due to scheduling of the CRBRP Qualification test.

B. SUMMARY

The following is a summary of tests conducted:

1. Base Line Data

The seals used for all previous CRBRP qualification tests (Ref. 2 and 3) were visually inspected, cleaned, and re-lubricated

with ~60 gm of Dow Corning 55M grease. The fixture cover plate was replaced and set with the nominal 0.12 in. vertical and 0.04 in. horizontal seal-to seal striker blade total indicated runout (T.I.R.). Drag vs speed vs inflation pressure parametric tests, dynamic leakage tests, static leakage tests, were conducted at ambient and 150 degrees F to establish that the performance of the seal was unchanged from prior testing.

2. Narrow Blade Tests

The 0.12 in. wide blade-track assembly was installed in the test fixture and the parametric tests and leakage tests were repeated at ambient and 150 degree F at the nominal 0.04 in. horizontal T.I.R. A 300 hr. dwell-breakaway test was conducted at 150 degrees F. The parametric tests and leakage tests were repeated at horizontal offsets of 0.18, 0.28, and 0.38 in. T.I.R. at 150 degrees F only.

3. Low-Friction Seal Coating Tests

The teflon-coated seals and 0.25 in wide seal blades were installed in the test fixture and the 150 degree F parametric and leakage tests were repeated. A second 300 hr. dwell-breakaway test was conducted. All tests were run at the nominal 0.04 in. T.I.R. horizontal offset.

4. Combined-Narrow Blade, Coated Seal Tests

These tests were not conducted due to the required use of the test fixture for the CRBRP Seal Qualification Tests.

V. TEST RESULTS AND RECOMMENDATIONS

Results of the narrow blade radial compliance and the coated

seal breakaway drag tests are presented below. Tests were conducted per N707DTP810016, as summarized above with the noted exceptions. Details of testing are recorded in AI laboratory notebook N17044.

A. Drag as a Function of Radial Offset

Figure 3 shows the running drag as a function of horizontal T.I.R. for the narrow (0.12 in. width) and the standard (0.25 in. wide) bladed tracks. All data for the narrow blade was generated from these tests while the standard blade data was taken from Figure 11 of reference 3 (N707TR810010) and is included for comparison. Base line datum using the standard blade at the nominal 0.04 in T.I.R. (indicated by an asterick) is consistent with the previous data. The substantial overall decrease in drag with the narrow blade was unexpected, but consistant throughout all test dequences. No increase in drag was observed with the narrow blade up to a T.I.R. of 0.18 in. Beyond that, drag showed an increasingly sharp rise as the offset was increased and the inflation pressure had to be increased significantly to maintain zero cross-seal leakage. The 0.50 in T.I.R. test was deleted as interference between the seal and blade sidewalls was excessive and judged to be sufficient to damage the seals. Using the narrow blade should allow increasing the maximum T.I.R. to 0.30 in without excessive drag or cross-seal leakage.

Figure 4 shows the running drag as a function of inflation pressure for the horizontal offsets of Figure 3. These data are consistent with previous data for the nominal blade showing an increase in drag with increasing inflation pressure and are of the same general magnitude as those of Figure 3 showing narrow blade drag to be significantly less than that of the standard width blade.

Similar data are shown in Fig. 5 for the uncoated seals with the standard and narrow blades and for the coated seals with the

0.04 TIR *
 0.18 +
 0.28 ◇
 0.38 ▽

AMB Δ NOMINAL $\circ$ NARROW NA COATED ----- AMB
150 $\blacksquare$ * $\blacktriangledown$ ----- 150F

standard blade. Data is presented for both ambient and 150 degree F at the nominal 0.04 in. T.I.R. These data emphasize the reduction (particularly for the ambient tests) in drag achieved with the narrow blade. The coated seal data falls generally in between, but approaches the standard blade data at the nominal 7.5 psig inflation pressure.

B. DRAG VS SPEED TESTS

Figure 6 shows running drag vs seal speed for the narrow blade with the various offsets and , consistent with previous data, shows little effect of speed over the given range. Figure 7 shows similar data for the coated and uncoated seals, the latter with both the narrow and standard blades. The general trend is the same except for the standard blade--uncoated seal combination which exhibits a more pronounced effect.

C. DRAG VS TEMPERATURE

Figure 8 shows the running drag as a function of temperature for the uncoated seal with the standard and narrow blades, both at the nominal 0.04 in. T.I.R. Data is consistent with previous tests and again shows lower drag for the narrow blade. As the ambient tests were deleted for the narrow blade offset tests and the coated seal tests, no temperature dependent data was measured.

D. 300 HOUR DWELL-BREAKAWAY DRAG TESTS

Due to the need of the test fixture for the CRBRP Qualification Seal Tests, the planned 1600 Hr. dwells were decreased to 300 hr. Two dwell-breakaway tests were run and the results are compared against those obtained from tests conducted with the standard width blade (Ref. 2). The first dwell-breakaway test was run with the narrow blade and the uncoated seals, and the second with the teflon coated seals and the standard width blade. Table I shows that while a

- * 0.04 TIR
- + 0.18 TIR
- ◇ 0.28 TIR
- ▽ 0.38 TIR

- STANDARD BLADE } UNCOATED SEAL
- * NARROW BLADE
- ▼ COATED SEAL, STANDARD BLADE

■ STANDARD BLADE
* NARROW BLADE

significant reduction in breakaway drag was obtained with the coated seals, no improvement was achieved with the narrow blade and uncoated seals.

TABLE I

SUMMARY OF 300 HOUR DWELL-BREAKAWAY DRAG TESTS

ITEM	COATED SEAL	NARROW BLADE	NOMINAL
Dwell Time (hr)	309	312	300
Temperature (F)	150 F	150 F	150 F
Breakaway Drag (lb/ft)	41.6	56.6	57
Drag after 1/4 Rev (lb/ft)	20.6	29.4	NA
Stabilized Dynamic Drag (lb/ft)	27.9	20.8	38

High breakaway is theorized to be the result of the lubricant being squeezed out from under the blade-seal contact area leaving a steel-elastomer friction surface. Once rotation is initiated, the seal is relubricated by its movement relative to the track. The teflon coating reduces the breakaway drag by acting as a low-friction surface in place of the lubricant, and once rotation is initiated, the effect of the teflon is minimized due to the reintroduction of the lubricant.

The teflon coating resulted in a 26% decrease in breakaway drag and, assuming this could be extrapolated, would decrease the 132 lb/ft

drag measured after the 3500 hour dwell to ~98 lb/ft. Additional testing should be run to evaluate the combined effects of the teflon coating, the narrow blade and reducing the seal speed during breakaway (which resulted in a 39% breakaway reduction, Ref. 3.)

E. DYNAMIC LEAKAGE TESTS

During each test phase and for each horizontal offset test, the cross-seal buffer cavity gas leakage rate was measured for various combinations of seal inflation and buffer cavity gas pressures. The various combinations are listed below and are the same as used in previous tests:

INFLATION PRESSURE P_I (psig)	BUFFER PRESSURE P_B (psig)
10	5.0
7.5 (1)	1.0 (1)
5.0	1.0
3.0	1.0

(1) Nominal Pressures

These tests were run at ambient and 150 degree F for the 0.25 in. wide standard blade "base line" tests and the 0.12 in. wide narrow blade tests, both at the nominal 0.04 in. T.I.R. All succeeding narrow blade tests (at 0.18, 0.28 and 0.38 in. T.I.R.) and the 0.04 in. T.I.R. tests with the coated seals and standard width blade were run only at 150 degree F.

Figure 9 shows the buffer cavity leakage rates for several combinations of blade width and seal offset, all at the nominal 15 ft/min. rotational speed. With nominal inflation and buffer cavity pressures of 7.5 and 1.0 psig respectively, there was no measurable leakage past the uncoated seals at 150 degrees F with the narrow blade. Leakage past the standard blade was 2 sccm at 150 degrees F where most previous tests showed zero leakage. At ambient, uniform leakage rates (irrespective of rotational position) of 3 sccm and 2 sccm respectively were measured for the narrow and standard width blades.

The effect of increasing the T.I.R. of the narrow blade is illustrated in the three curves generated with offsets of 0.04 (nominal), 0.180, and 0.38 in. T.I.R. Data from the 0.28 in. T.I.R. test were deleted because of a fixture leak at the buffer cavity gas inlet port. As would be expected, leakage increased as the T.I.R. increased. Also included for comparison is leakage for the standard width blade with 0.25 in. T.I.R. taken from Ref. 3. Note that the narrow blade leakage rates are considerably lower for similar offsets due to the decreased distortion of the seal side walls with the narrow blade. Note also that all leakage curves show a peak near the 60 degree seal angular position. This is the result of the test fixture 0.028 in. T.I.R. which is imposed on top of the nominal seal offset. This results in the once per revolution alignment of worst-case offset and subsequent leakage peak.

Similarly, leakage increases as the inflation pressure is decreased as illustrated by the curve showing a P_I of 5.0 psig. Conversely, leakage can be significantly reduced by over inflating the seals.

The coated seal-standard width blade configuration showed only slight leakage at 150 degrees F and the nominal 0.04 in T.I.R. This leakage was probably due to the crazing of the teflon coating which provided a myriad of tiny leak paths. The crazing was a result of the greatly differing flexibility of the elastomer and spray on teflon coating. Additional work would be required to incorporate the teflon coating and eliminate the interface problems.

F. STATIC THRESHOLD LEAKAGE TESTS

Figure 10 illustrates the inflation and buffer pressure combinations to obtain "zero" leakage for static seal conditions. Tests were run at the nominal 0.04 in horizontal and 0.12 in vertical T.I.R. at 150 degrees F. All buffer and inflation pressure combinations to the right of the curves resulted in no measurable leakage (< 0.1 sccm). Results are similar to those obtained before (Ref. 2) and show that the narrow blade is slightly more effective at sealing than the standard width blade.

BUFFER CAVITY THRESHOLD LEAKAGE
 AS A FUNCTION OF
 INFLATION AND BUFFER PRESSURE

FIGURE 10

■ STANDARD BLADE } UNCOATED SEAL } 0.04" T.I.R.
 * NARROW BLADE }
 ▼ COATED SEAL, STANDARD BLADE

6. SEAL INSPECTION

At the end of each test phase, the fixture lid was removed and the seals visually inspected for wear or damage. An insignificant degree of wear was observed as evidenced by slight darkening of the grease due to trace amounts of the elastomer being worn off and collected in the grease. The uncoated seals were completely cleaned of grease following the 0.38 in T.I.R. test and no signs of damage or wear was visible to the seal side walls. These seals were then removed from the test fixture to permit installation of the teflon coated seals. As with all bonded with Chemlok 304 epoxy adhesive, the seals were severely damaged during removal. The epoxy-to-gland bond is stronger than the seal itself and resulted in ripping of the bottom of the seals. This is illustrated in Figure 11 which shows parts of the seal base adhering to the gland. It was necessary to chemically dissolve the epoxy bond by methods prescribed in the Seal Removal Specification.

The FT-R-5 teflon coating was crazed around the entire circumference of both seals as received from Royal Industries following spray application and 350 degrees F curing of the coatings. This is shown in Figure 12. The cracking of the teflon was anticipated as it is a common problem in applying the relatively rigid teflon on the flexible elastomer surfaces. No further crazing was observed during testing and no visible loss of the teflon coating due to spalling or wear was observed after test.

H. CONCLUSIONS AND RECOMMENDATIONS

Use of the narrow (0.12 in wide) blade resulted in both a reduction in dynamic drag and an increase in radial compliance. At nominal operating conditions the dynamic drag was reduced from ~30 lb/ft to ~20 lb/ft at 150 degrees F, and the radial compliance was increased from 0.12 to 0.30 in T.I.R. before a significant rise in drag was observed. Due to the limited test period, it is recommended that additional tests be run at the conclusion of the CRBRP Qualification tests to verify data obtained here.

09006-40810

SEAL GLANDS AFTER REMOVAL OF SEALS
FIGURE II

9006 - 40810

COATED SEAL - POST TEST CONDITION

FIGURE 12

FFTF-IVHM COVER GAS SEAL TEST

FIGURE 13

IVHM RRP DYNAMIC SEAL REACTOR INSTALLATION

Dynamic Seal Test System Plumbing and Instrumentation Diagram
Figure 14

Use of the teflon coated seal reduced breakaway drag from 57 lb/ft to 42 lb/ft while use of the narrow blade with the uncoated seals showed no significant reduction in drag. It is recommended that tests be run with the narrow blade and coated seal combination to see if any further reduction in dynamic or breakaway drag or increase in radial compliance can be achieved.

Additional investigations must also be made into the proper techniques of applying teflon to the elastomer to prevent crazing of the coating. One promising technique is the application of a strip of teflon on the seal wear surface prior to curing the green elastomer.

VI. TEST METHODS AND INSTRUMENTATION

A detailed discussion of the inflatable seal test assembly and instrumentation is presented in Ref 2, Section IV. Figure 13 shows the test fixture and instrumentation, and Figure 14 shows a schematic of the gas pressurization and drive systems.

VII. DISPOSITION OF THE TEST ARTICLES

The inflatable seals (one set each uncoated and coated) were removed from the test fixture at the conclusion of various test phases. These seals were damaged such as to prevent future use, but will be stored by Dept. 731 in Bldg. T006, AI, Santa Susana, for possible use as "ozone resistance" specimens. The standard width blade assembly will be retained for the CRBRP Vendor Qualification test series, and the narrow blade track assembly will be stored for possible future testing per recommendations of section V, G.

VIII. REFERENCES

1. TR-707-810-004, "Test Report, IVHM Reactor Refueling Plug Dynamic Seal Test", W. Kurzeka and A.G. Stewart, 5/18/74
2. TR-707-810-009, "Test Report, CRBRP Rotating Plug Inflatable Seal," H. Deboi, 6/27/75.
3. N707TR810010, "Test Report, CRBRP Rotating Plug Inflatable Seals: Special Tests," P. Horton, 2/25/76 .
4. N707TP810014, "Dynamic Inflatable Plug Seal Improvement: Test Plan," P.Horton, 12/14/76.
5. N707DTP810016, "Dynamic Inflatable Plug Seal Improvement: Development Test Procedure," P. Horton, 1/25/77.

IX APPENDIX

1. Seal Track Purchase Documents
2. Teflon Coating Purchase Documents

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 SERIAL NUMBER _____
 MATERIAL CONTROL NUMBER _____
 LOT NUMBER _____

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JAN 28 1977

By

L. J. McClurey
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L. J. McClurey

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N707TR810014 PAGE 33

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SPECIAL INSTRUCTIONS

Hank Van Heman

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TF-R-5 (Greenish-Blue) supplied in place of because TF-R-6
spelled on application.

The undersigned certifies that the items shipped herewith are in conformance with all purchase order requirements. Physical and/or chemical test reports of the materials used in said items are on file.

MAT'L SPEC. _____

BATCH NO. _____

TETRAFLUOR DIVISION
[Signature]
DIRECTOR OF QUALITY CONTROL

ROYAL INDUSTRIES

TETRAFLUOR DIVISION

CERTIFICATION OF CONFORMANCE

COMPANY ROCKWELL INTERNATIONAL CORP. PURCHASE ORDER NO: N74500125MP
SHIPPER NO 22602 DATE 4/26/77
MATERIAL: PTFE TYPE: _____ BATCH NO: 854 & 757

THIS IS TO CERTIFY THAT THE FOLLOWING PART NUMBERS AND QUANTITIES HAVE BEEN MANUFACTURED IN ACCORDANCE WITH ALL APPLICABLE SPECIFICATIONS. ORIGINAL CERTIFICATIONS COVERING MATERIALS AND PROCESSES ARE ON FILE SUBJECT TO YOUR EXAMINATION:

2 PCS. COATED CUSTOMER FURNISHED SEALS PER SPEC
TF-R-6 AND CUSTOMER INSTRUCTIONS FOR
CLEANING, CURING & MASKING FLYSHEET #1,
FIGURE 1, 740-R, 740-R-1, N70-C-20-9-75

MATERIAL SPECIFICATION (S):

☐ AMS-3651C☐ MIL-R-8791C☐☐

TETRAFLUOR

MICHAEL ROACH

DIRECTOR, QUALITY ASSURANCE