General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

NASA CR-
144435

ILC DOVER

FINAL REPORT ON DEVELOPMENT OF A SEALED BEARING FOR SPACE SUITS

(NASA-CR-144435) ON DEVELOPMENT OF A SEALED BEARING FOR SPACE SUITS Final Report (ILC Industries, Inc., Dover, Del.) 15 p HC $3.25 CSCL 06K

N75-31743

Unclas
G3/54 35063

Prepared Under
Contract NAS 9-14399

For

National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas 77058

RECEIVED

J. F. Rayfield

J. Rayfield, Project Engineer

John McMullen

J. McMullen, Manager
Space and Environmental Systems

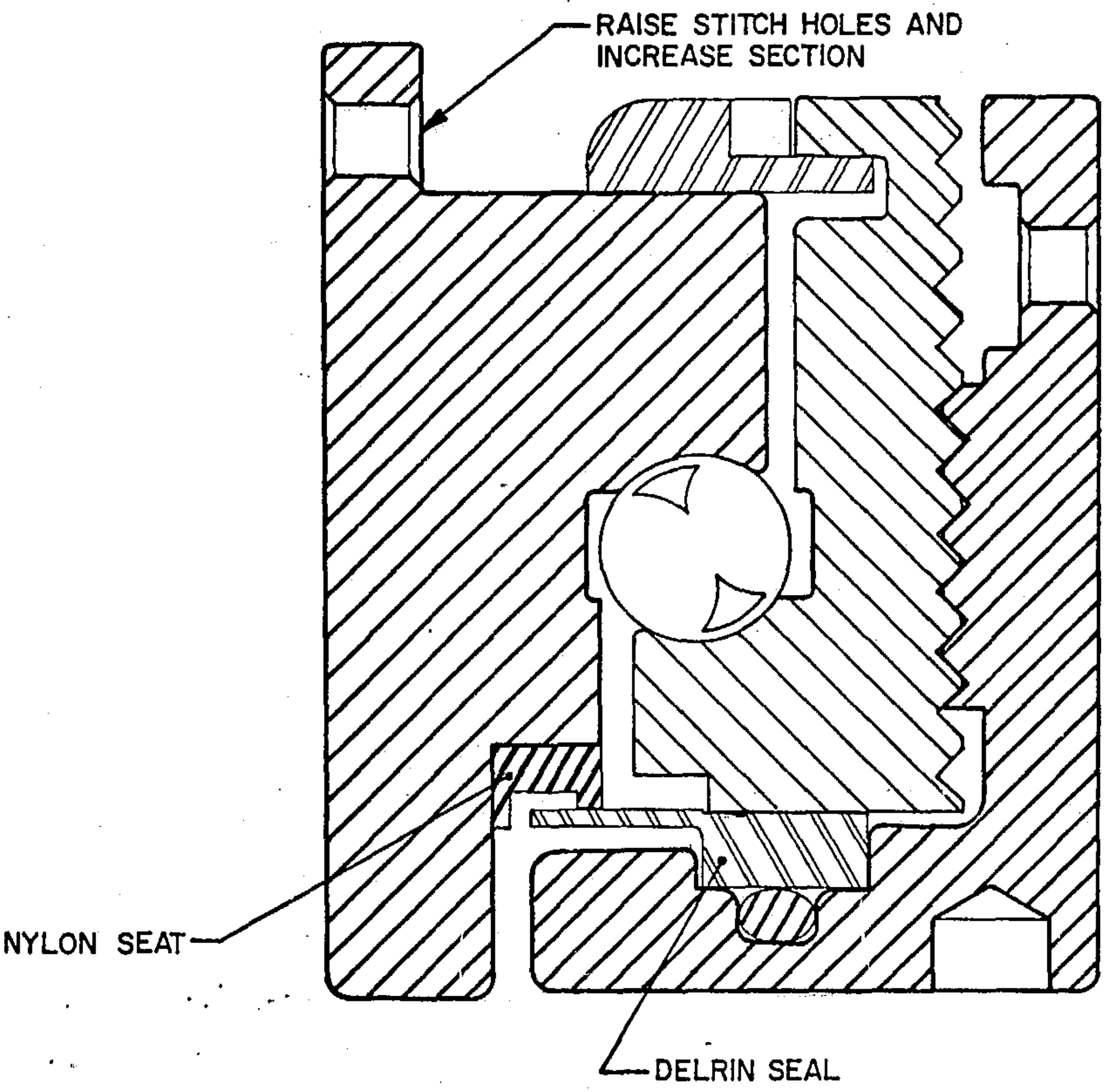
1.0 INTRODUCTION

This report summarizes the work performed under Contract NAS 9-14399, for the development of a sealed rotary bearing for use in mobility joints for space suits.

The purpose of this program was to correct several design deficiencies present in the bearings used in the Orbital Extravehicular Spacesuit (OES) developed under Contract NAS 9-13257.

These deficiencies included: difficult stitch-on interface between fabric and outer race; a tendency for the clamping threads to seize; and, most importantly, the failure of the sealing surfaces (Teflon seat, Delrin seal) to maintain integrity with cycling. The first problem was corrected by raising the stitch-on holes so as to be more accessible. The seizing was eliminated by changing to a coarser thread, from 32/inch to 24/inch. The solution to the sealing problem required a materials evaluation, candidate material selection, and adhesive evaluation (for bonding the seat material to the outer race) and bench-cycling of candidate seal/seat combinations.

The final configuration, successfully bench-cycled and delivered to NASA, is shown in Figure 1.



SEALED BEARING CROSS SECTION

FIGURE 1

A further problem, the upsetting of the seal by race distortion, in turn caused by improper loading of the scye bearing outer race by the OES torso fabric, was not addressed in this effort. This was due to the limited funds and to the very real possibility the torso loading would be radically improved in future suits, either by fabric re-patterning or by the switch-over to a hard-shell upper torso.

2.0 SEAL/SEAT INVESTIGATION

The remainder of this report describes in detail the seal/seat improvement effort.

2.1 CANDIDATE MATERIALS SELECTION

The basic problem with the original OES bearing seal/seat was determined to be due to galling of the 100% Teflon seat used in that design; use of lubricants at the seal/seat interface reduced the rate of galling, but also entrapped Teflon debris at the interface. Any such debris at the interface caused serious leakage.

The need, therefore, was to find alternate materials, for the seal and/or seat, which would not produce the galling effect a[illegible]d also be acceptable in terms of availability, ease of machining, overall durability, dimensional stability, compatibility with spacecraft materials requirements, and low coefficient of friction. Since the Delrin seal appeared to be acceptable as is, it was decided to limit the initial search to the seat materials.

Literature evaluation and vendor consultation narrowed the candidates to three materials: Nylon, Delrin, and Delrin "AF" (75% Delrin/25% Teflon).

2.3 ADHESIVE EVALUATION

Based on DuPont design handbook recommendations for bonding of Nylon and Delrin to stainless steel, vendors were contacted to obtain samples of those adhesives yielding the highest shear strengths. It was found that the handbooks, although recently printed, contained considerable misinformation, in that some adhesives had been discontinued, some had been "sold" to other vendors, and others had been redesignated either by name or number. However, after extensive coordination, samples of several candidates were obtained. Test samples were assembled using these adhesives and various surface preparations. The samples consisted of strips of 17-4 PH stainless steel cemented to blocks of Nylon, Delrin and Delrin AF. The samples were pulled in shear on the Instron tensile tester and the force required to break the bond recorded. The shear strength was then calculated by dividing this force by the area of the bond.

Table I summarizes the data acquired. Based on these tests, it was apparent the DuPont No. 56049 contact cement would suffice for the 100% Delrin and possibly for the Nylon, while the APCO R-363 epoxy would be adequate for the Delrin AF. In all cases, sanding the surfaces increased bond strength appreciably; chemical etching had a lesser effect. (A DuPont etching process called "satinizing" produces the best results with Delrin, according to DuPont, but it is somewhat unwieldly, requiring a dip, oven heating, water rinse, and oven drying.)

The DuPont No. 56049 contact cement is the simplest to use: the surfaces are roughened; the cement is applied and allowed to dry; the bond is achieved by placing the parts in contact, applying pressure (from 10 to 20 psi), and oven heating to 113°C (235°F) for a short time (heat re-activation). This technique allows greater flexibility in production and field maintenance than do the two-part adhesives.

2.3 CYCLE TESTING

The first configuration selected for cycling was a test-bed scye bearing with a nylon (Zytel) seat bonded to the outer race with heat re-activated DuPont cement No. 56049, and a 100% Delrin seal. The balls and seal were lubricated with Krytox oil. The bearing assembly

ADHESIVE PERFORMANCE TESTS
SHEAR STRENGTH (2)

ADHESIVE	DELRIN AF	DELRIN	NYLON
E.I. DuPont No. 56049 adhesive (Contact Cement) Heat reactivated	143 PSI 180 PSI both tests - surfaces etched[1] prior to applying adhesive	410 PSI (sanded surfaces) 384 PSI (non-roughened) [251 PSI (surface etched[1] 277]PSI prior to applying adhesive.)	237 PSI 269 PSI both tests surface etched[1] prior to applying adhesive.
Koppers "Penacolite G1124" ith Borden Co. NT-442 primer on stainless steel.	Not recommended	Not recommended	283 PSI (roughened surface)
APCO (Applied Plastics Co.) R-363. 2 parts epoxy. Surfaces roughened	326 PSI	216 PSI	806 PSI

NOTES:

[1]Etched with "Tetra-Etch"; this is used primarily as a Teflon etchant.

[2]Compare these valves to 380 PSI for Teflon/stainless steel using etch plus "Chem-Grip adhesive, as on OES.

TABLE I
ADHESIVE PERFORMANCE TESTS

was mounted in the GFE test fixture. Leakage was less than 4 scc/min; running torque was 20 inch-lbs. After 3,000 cycles (from 0° to 200° and return to 0° counted as one cycle) leakage was 20 scc/min and torque was 20 inch-lbs. After 5,000 cycles, leakage had increased to 200 scc/min and torque was still 20 inch-lbs. At this point the bearing was disassembled and inspected. Microscopic examination revealed considerable build-up of debris on the seat, apparently captured by the Krytox grease. The seal and seat were cleaned thoroughly and were not re-lubricated. The assembly was put back into test with an initial leakage of less than 4 scc/min and a torque of 20 inch-lbs. At a (cumulative) total of 20,058 cycles, the leakage was 6 scc/min and the torque had decreased to 12 inch-lbs. From this point to 50,084 cycles, the torque continued to decrease to a final value of 8 to 10 inch-lbs. The leakage remained at the 4-6 scc/min level.*

At this point, it was decided to obtain cycle data on the Delrin AF material. The bearing assembly was therefore disassembled and a Delrin AF seal was substituted

---

*It should be noted that in the extensive bearing testing performed during the OES program the Teflon seat/Delrin seal combination was also tested without lubricant. This was a far worse arrangement than with the lubricant: leakage was 500-1000 scc/min and developed within only 5-10 cycles.

for the 100% Delrin seal. The nylon seat was left in place. The seal and seat were cleaned, but not lubricated. This combination was run for 24,050 cycles, with periodic checks of torque and leakage. Leakage was slightly higher and more erratic than with the 100% Delrin seal. Torque was not appreciably different, varying from 8 to 12 inch-lbs. At 24,050 cycles, a large and erratic leakage was evident. Inspection revealed that the Delrin AF seal showed a white deposit (probably Teflon) in the area of seat contact. Since it appeared to have the same galling properties as 100% Teflon, and no advantages over 100% Delrin, the Delrin AF was abandoned.

At this point it was suspected that the 70,000-odd cycles had worn out the nylon seat. Accordingly, a new nylon seat and a new 100% Delrin seal was installed and the test series started again. Initial leakage was 15 scc/min at 4.0 psid, torque was 12 inch-pounds. After 2,790 cycles, leakage was unchanged and torque had dropped to 9.6 inch-pounds. From this point until the test was terminated at 105,015 cycles, leakage remained in the range of 9 to 16 scc/minute. Final torque was 8.8 inch-pounds.

Since this test was successful, it was decided to use the test-bed bearing for DVT. Accordingly, the bearing was disassembled, cleaned and inspected. The sew-on holes were then drilled and de-burred. Another new

Delrin seal/nylon seat set was installed along with new O-ring, balls and spacers. When re-assembled, leakage was 140 scc/minute. After 2,000 cycles, the leakage was still over 100 scc/minute and erratic. Several attempts were made to isolate the problem; the seat-race interface was coated with the contact cement used to bond the seat to the race; a seal with greater interference (.002 inch as opposed to 0.0005 inch) was machined and installed; the seal from the successful (105,000 cycle) test was installed. None of these fixes was successful. At this point, since a NASA-JSC visitor was at Dover, and it was desired to install the bearing in the OES for manned evaluation, the bearing was hand-carried to JSC. Subsequent evaluation by JSC revealed that an uneven (chatter) area was present at the sealing face of the O-ring groove. Apparently, the new O-ring was slightly smaller than those used in the test series and therefore did not seal over the chatter area. This was verified by applying grease to the O-ring; this reduced leakage to 6 scc/minute. The leakage again went up to over 100 scc/minute when the grease was removed and was again reduced when the grease was replaced. This bearing was installed in OES 001 and man-cycled at JSC.

Bench cycle test results are summarized in Tables 2, 3, and 4.

CYCLING DATA

NEW OES BEARING

Series #1

(Seat: 6-6 Nylon ("Zytel")
(Seal: Delrin (100%)

f = 1440 CPH
P = 4.0 psig

Cycles	Leak $\frac{scc}{min}$	Torque in.-lbs	Remarks
3,000	20	20	Lubed w/Krytox
5,000	200	20	Debris on seat. Cleared and not lubed. Restarted.
5,000+	<4	20	
20,058	<4	20	Taken apart, no apparent wear. Cleaned with Freon. Restarted.
20,058	~6	12	
46,752	<4	8-10	Run over night. Restarted.
50,084	<4	8-10	Stopped testing.

TABLE 2

CYCLING DATA

NEW OES BEARING

Series #2

Same seat as used in Series #1
Delrin AF seal

f = 1440 CPH
P = 4.0 psig

Cycles	Leak $\frac{scc}{min}$	Torque in.-lbs	Remarks
0	8	20	Dry No lube
1,392	8	11.2	Clean, replace balls & spacers Lube race
4,000	20	12.0	Race lubed
4,000	20 cc	8.0	
7,716	20 cc	12.0	
7,716	20 cc	8.0	
11,363	5 cc	10.0	
11,363	5 cc	10.0	
15,799	6.5	8.0	
20,303	9.5	8.0	
24,050	145 cc	14.0	Excessive wear on seat, Teflon debris apparent.

TABLE 3

CYCLING DATA

NEW OES BEARING

Series #3

Seat:
6-6 Nylon (Zytel)
Seal: Delrin (100%)

f = 1440 CPH
P = 4.0 psig

Cycles	Leak $\frac{scc}{min}$	Torque in.-lbs	Remarks
0	15 to 45	12	Cleaned & lubed ball race.
2,790	15	9.6	
5,235	15	10.0	
13,553	10 sccm	9.6	
36,000	14	9.6	
46,600	9	8	
68,020	16	9.6	
78,835	11	12.0	
105,015	10 scm	8.8	No significant wear on seat or seal

TABLE 4

2.4 END ITEM FABRICATION AND TEST

The end item scye bearing was fabricated to the same configuration as the test-bed bearing. However, in order to evaluate one more alternate approach, a steel (17-4 PH) seat was installed in the outer race. Leakage was high and erratic (from 80 to 500 scc/min) even after 3,000 bench cycles. Examination showed very high wear on the Delrin seal. It was concluded that the steel seat was too hard to form a gas tight interface with the Delrin seal.

Accordingly, the bearing was equipped with a nylon seat and a new Delrin seal. Leakage was less than 4 scc/min, torque was 14-16 inch-pounds. As a check, the OES arm/ shoulder was installed on the inner race, the bearing was assembled, and the outer race installed in the bench test fixture. A bubble check at 4 psid showed no leakage present. This was done to verify that if the bearing was held sufficiently rigid on the outer race side, no leakage would be expected when installed in a suit.

The end item bearing was then installed in OES 001 and the suit returned to JSC for further evaluation.

3.0 CONCLUSIONS AND RECOMMENDATIONS

Based upon the results and observations evolved from this effort, the following conclusions and recommendations are made:

1. The 6-6 Nylon seat/100% Delrin seal combination provide both low leakage and low torque in the OES bearing and enable the bearing to meet all requirements of the statement of work.

2. The seal/seat should not be lubricated. Lubricants did not noticeably reduce torque or wear, and were, in fact, detrimental in that they can collect debris and thus upset the gas seal significantly.

3. A "burn-in" of a new seat/seal is desirable prior to installation of a bearing in the suit; this could consist of 2000-3000 bench cycles in a test fixture. This will assure that minimal torque is present at suit installation.

4. If this (shoulder) bearing design is ever to be used in a fabric torso, some action must be taken to alleviate the severe off-design loading condition imposed by the fabric in the OES 001; alternatively, the bearing outer race could be re-configured and/or re-sized to enable it to take this loading without excessive deflection.