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IMPROVED SEAL FOR GEOTHERMAL DRILL BIT

Final Technical Report

By
R. F. Evans

July 6, 1984

Work Performed Under Contract No. FG01-82CE15104

Robert F. Evans
Dallas, Texas

Technical Information Center
Office of Scientific and Technical Information
United States Department of Energy

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IMPROVED SEAL FOR
GEOTHERMAL DRILL BIT
Final Technical Report

Energy Related Inventions Research
and Development
Grant DE-FG01-82CE-15104

July 6, 1984

Robert F. Evans
Dallas, Texas

Final Technical Report
Improved Seal for Geothermal Drill Bit

In pre-test discussions with Drilling Research Laboratory personnel, it was pointed out that there were several new high temperature lubricant candidates which had appeared since any laboratory testing had been done. It was decided to do the laboratory lubricant testing in order to start the seal tests with the best available lubricant. The letter report of January 26, 1983, reports the results.

The Pacer PLX-139 was selected as the lubricant to be used in the seal tests because of its unusually high load capacity and low coefficient of friction. The Pacer Geobond grease was the first choice prior to this test.

SEAL TESTS

After the caliper sealing elements were designed a meeting was held with Drilling Research Laboratory personnel to discuss the test details and get dimensions needed for designing the special seal carrier details.

The decision to use AFLAS 150 Elastomer as a material for molding the seals was made. Its high temperature properties and resistance to most chemical substances were the basis for this choice.

The seals were molded and the seal carriers machined and the testing commenced. The letter report dated March 30, 1983, is the documentation of the first tests. The seals were not effective and it was believed that the high hardness and stiffness of the AFLAS material was the cause. It was decided to mold new seals of a softer more compliant elastomer, Viton.

Letter report dated June 20, 1983, reports the data of the Viton seal test. Sealing was again not achieved and it was decided to terminate the testing at the Drilling Research Laboratory and fabricate a room temperature test fixture to investigate the cause of leakage. This was done using a drill press to drive the seal holder. After hours of testing it was determined that a bias force provided by a light Bellville spring is required to initiate sealing. Pressure increases from inside or outside the bearing then provide positive sealing.

Remaining funds were too limited to go back to the Drilling Research Laboratory for elevated temperature tests and it was doubtful that any Geothermal drilling company would field test

a bit without a good laboratory report, hence it was decided to fabricate and field test bits for air drilling in the oil fields. Air drilling provides a high temperature test and success would undoubtedly provide data of interest in Geothermal drilling and make possible a Geothermal test.

THE BIT TESTS

The Varel Manufacturing Company of Dallas, Texas built two 7-7/8 inch bits having the special caliper seals. They were both the International Association of Drilling Contractors type 617. Field test results are given.

FIELD TEST ONE

Bit run by Cubby Drilling of Midvale, Ohio, in Carroll County, Ohio.

Feet drilled	3,075
Hours	23.7
Feet per hour	129.7
RPM	90
Weight on bit	40,000 lbs.

Bit is very dull. Two seals are out and Tungsten carbide cutting structure is about three fourths dull.

FIELD TEST TWO

Bit run by G & D bit service in Moore County, Texas.

Feet drilled	3,109
Hours	51.8
Feet per hour	60.0
RPM	80
Weight on bit	30,000 lbs.

This bit drilled at a low penetration rate because it was the wrong I.A.D.C. type cutting structure for this particular formation. With a I.A.D.C. type 537 this interval is commonly drilled in 28 to 30 hours.

CONCLUSIONS

Each of the two field test bits showed some promise though their performances were less than commercially acceptable.

The Ohio test bit ran just over 3,000 feet where about 4,000 is considered a good run but it was noted that a Varel bit of the same type having a standard O ring seal was completely worn out after 8½ hours (1,750 feet drilled).

The Texas test bit had good seal-bearing life but was the wrong cutting structure type for the formation being drilled and the penetration rate was low.

Since these two tests did not provide data which would interest a contractor drilling in Geothermal work, it is planned to repeat a two bit oil field test program beyond the term of this contract.

AFLAS

150 Heat- and Chemical-resistant Fluororubber

ASAHI GLASS

Long Use at a Temperature of 230°C

Features of the New Fluoro Rubber

Heat Resistance

- Can be used continuously at a high temperature of +230°C.
- Can withstand +260°C for a shorter period of time.

Chemical Resistance

- Not affected by chemicals such as acids, alkalis, sodium hypochlorite, etc.
- Capable of providing a level of chemical resistance equal to that of a fluororesin.

Steam and Hot Water Resistance

- Will not hydrolyze on exposure to high-pressure steam or hot water, and consequently, will maintain its elasticity for a long period of time.

Non-Toxic and Odorless

- Has passed the Food Sanitation Test under Notification 434 of the Ministry of Health and Welfare of Japan, and consequently, is safe for use in food processing plants, etc.

Representative Applications

For Plate-type Heat Exchanger

Plate-type heat exchangers are used for pasteurizing milk or for cooling sodium hypochlorite. Ever since the gaskets on these units were changed to AFLAS 150, the continuous operating time has been more than quadrupled and maintenance has been facilitated.

AFLAS 150 is available as a steam-resistant compound — AFLAS 150TS. This AFLAS compound is several times more durable than that of similar heat-resistant rubbers, and represents the optimal material to be used for rubber parts that are to be in direct contact with high-temperature steam.

For Diaphragm Valves

When AFLAS 150 was used for the diaphragm of diaphragm valves which are frequently used in chemical devices, the result was that the life span of the valve was lengthened and the maintenance of the device was facilitated. Valves that are used in such chemical devices must be tough as they are constantly being exposed to chemical fluids such as acids and alkalis; and the performance of the diaphragm is what determines the life span of the valve, not to mention its maintenance.

The AFLAS 150's high level of resistance to chemicals, especially hot acids and alkalis, is making it indispensable for use in rubber parts which are exposed to chemical fluids.

For Hoses Handling Chemicals

The life span of transportation hoses for sulfuric acid, nitric acid, etc. has been substantially lengthened by the adoption of AFLAS 150.

The highly reliable performance of AFLAS 150 becomes invaluable especially when the transportation of corrosive chemicals, high-purity chemicals or high-temperature chemical solutions is involved. AFLAS 150 is also used in steam hoses for steam irons. AFLAS 150 is guaranteed to maintain all the properties of rubber for a long period of time — even under high-temperature or high-pressure steam conditions.

For Flexible Joints

Flexible joints which are used to absorb the heat expansion and vibrations of piping networks are required to be durable enough to withstand heat as well as the liquid flowing within the pipes. Furthermore, these joints must possess a high level of flexibility and elasticity.

Flexible joints made with AFLAS 150 have proven to be equal to cut-into-shape fluororesin flexible joints in resistance to heat and chemicals. However, these joints are better able to absorb heat expansion and vibrations, making them the optimal choice for underground piping.

Other Uses

Packing, gaskets, O-rings, shaft seals

Tank trucks for sulfuric acid, hydrochloric acid, hypochlorous acid, etc. / textile bleachers / electrolyzers / plating vessels / pressure cookers / heat exchangers / corrosion-resistant pumps / exhaust ducts / pollution measurement instruments / pesticide sprayers / boilers / food sterilizers / industrial injectors for alcoholic beverages and soft drinks

Valve seats and diaphragms

Exhaust gas desulfurizers / acid-resistant valves / steam valves / textile bleachers / corrosion-resistant pumps / pollution measurement instruments / pesticide sprayers / industrial machines and devices for food production

Rollers

Pickling machines / textile bleachers / copy machines, etc.

Sleeves, hoses, tubes

Tank trucks for sulfuric acid, hydrochloric acid, hydrochlorous acid etc. / piping for various types of chemicals / electrolyzers / plating vessels / exhaust ducts / pumps for hot-air blowers / various types of laboratory instruments, etc.

Belts, rubber cloths, etc.

Acid-resistant clothing / dryers / conveyor belts, etc.

The data on the following pages are provided for reference only. Asahi Glass accepts no responsibility for the results obtained therefrom or for their utilization in infringement of patent rights.

Standard Properties of Vulcanized AFLAS 150 Products

[Formulation]			[Compression set] JIS K6301		
Polymer		100	200°C x 22 hrs.		23
Peroxyimon F-100 (a)		1	200°C x 70 hrs.		32
Triallyl isocyanurate (b)		5	[Aging at high temperatures] JIS K6301		
MT carbon black (c)		35	After 10 days at 260°C		
Sodium stearate		2	Tensile strength	kg/cm ²	92
[Vulcanization]			Elongation at break	%	296
Press		180°C x 10 min.	100% modulus	kg/cm ²	33
Oven		180°C x 1 hr. → 200°C x 1 hr. → 230°C x 2 hr.	Hardness	JIS A	75
[Properties under normal conditions]			[Resistance to chemicals]		
JIS K6301			After being dipped for 3 days at 100°C	Volume change	Hardness change
Tensile strength	kg/cm ²	164	96% sulfuric acid	4.2	0
Elongation at break	%	276	60% nitric acid	21.0	-10
100% modulus	kg/cm ²	42	50% caustic soda	0.1	0
Tear strength	kg/cm ²	31	10% sodium hypochlorite	0.1	0
Hardness	JIS A	74	Pure water	5.3	-2
			ASTM #3 oil	5.8	-2

- (a) α, α' bis (tertiary-butyl-peroxy) diisopropylbenzene made by Japan Oil and Fat Co., Ltd.
(b) Triallyl isocyanurate made by Nihon Kasei Chemical Corp. Ltd.
(c) Thermax MT made by Vanderbilt

Unique Structure of AFLAS 150

AFLAS 150 has a structure in which tetrafluoroethylene (C_2F_4) and propylene (C_3H_6) are arranged alternately in an orderly manner.

Standard Composition of AFLAS 150 Compounds

Compound	150H-60	150H-70	150H-80	150H-90	150TS	
[Formulation]						
Polymer (AFLAS 150)	100	100	100	100	100	
Peroxymon F-100	1	1	1	1	1	
Triallyl isocyanurate	5	5	5	5	5	
Sodium stearate	2	2	2	2	2	
MT carbon black	5	25	50	80	10	
Alumina (WA#8000)					10	
Aerosilsilica					20	
[Properties of Vulcanized Products]						
Tensile strength	kg/cm ²	223	210	193	181	215
Elongation at break	%	370	267	185	130	240
100% modulus	kg/cm ²	19	37	78	136	117
Hardness	JIS A	62	71	82	90	91
Compression set	%	20	18	20	27	17
(200°C x 22 hrs.)						
Tear strength	kg/cm ²	18	31	35	36	47

Heat Resistance of AFLAS 150

AFLAS 150 possesses excellent resistance to aging at high temperatures. Even when used over long periods at 200°C, AFLAS 150 does not lose its special qualities. It can be used continuously for sixty days at 230°C and for ten to thirty days at 260°C. It is even possible to use it for short periods at temperatures close to 300°C.

Steam Resistance of AFLAS 150

	Tensile strength kg/cm ²	Elongation at break %	100% tensile stress kg/cm ²	Hardness JIS A	Permanent elongation %	Adherence to metals kg/cm	Resistance to tear kg/cm	Compression set % (100°C x 22 hrs.)	Repulsion elasticity %
Values under normal conditions	156	300	43	77	14	13	33	26	5
Under steam 200°C x 6 hrs.	132 (-15.4)	350 (+16.7)	37 (-14.0)	76 (-1)	18	8	29	16.4	4
x 18	126 (-19.2)	350 (+16.7)	36 (-16.3)	75 (-2)	20	12	30	22.1	4
x 24	118 (-24.4)	340 (+13.3)	34 (-20.9)	74 (-3)	20	11	31	37.2	4

Resistance to Chemicals of AFLAS 150 (volume change in %)

Chemical	Temperature (°C)	Time (day)	AFLAS 150	Fluoro-rubber	Silicon rubber	Ethylene-propylene rubber	Chloro-prene rubber	Butyl rubber	Nitrile rubber	Hypalon
Fuming sulfuric acid	23	7	4.2	23.0	X	X	X	X	X	X
96% sulfuric acid	100	3	4.4	48.0	X	X	X	X	X	X
60% nitric acid	23	7	1.3	13.0	13.0	X	X	X	X	X
50% fluoric acid	23	7	1.5	11.0	X	13.0	62.0	0	138	4.1
37% hydrochloric acid	40	3	2.3	32.0	-29.0	6.2	18.0	-	14.0	-
20% caustic soda	100	3	2.0	46.3	1.2	-1.2	-0.9	-2.7	-5.4	-2.0
28% ammonia solution	70	3	3.2	5.3	-2.8	0.1	9.5	4.0	1.8	18.0
Hot water	100	3	1.1	5.9	2.0	0	12.0	-0.1	12.0	4.0
Steam	160	7	4.6	12.8	-	0.7	-	2.1	-	-
Steam	200	3	4.9	20.0	X	7.0	-	7.8	-	-
10% sodium hypochlorite	100	7	1.0	X	-	-	-	-	-	-
Methanol	23	7	0.2	51.0	-	-	-	-	-	-
Acetone	23	7	50.0	200	20.0	-	-	-	-	-
Ethyl acetate	23	7	88.0	280	-	-	-	-	-	-
Aniline	23	7	0.7	3.0	3.0	-	60.0	5.0	210	35.0
Benzene	23	7	31.0	20.0	140	-	150	75.0	125	220
n-Hexane	23	7	24.0	1.3	-	-	-	-	-	-
Carbon tetrachloride	23	7	86.0	1.3	315	-	330	275	55.0	350
Trichloroethylene	23	7	95.0	10.0	240	-	280	240	180	500
ASTM #3 oil	100	3	7.9	1.5	23.0	-	40.0	60.0	2.6	40.0
Gasoline	23	7	25.0	3.1	260	-	55.0	240	6.0	85.0
Kerosene	23	7	5.0	1.3	-	-	-	-	-	-
Engine oil	150	5	4.1	9.7	10.1	-	-	-	2.8	-
Gear oil	100	5	1.1	8.5	4.2	-	-	-	1.3	-
Brake oil	100	5	8.8	X	2.8	-	-	-	90.4	-
Phosphoric acid ester oil	23	7	1.4	260	-	-	-	-	-	-

X: disintegration or dissolution

DRILLING RESEARCH LABORATORY

January 26, 1983

Mr. Robert Evans
P. O. Box 45874
Dallas, Texas 75235

Dear Bob,

The laboratory tests are now complete, and the results are very encouraging. In this letter I will summarize the test conditions and results, and compare them with our previous work. Enclosed are the wear rings and blocks, force graphs, and a post-test sample of each lubricant.

The test conditions were the same as were used for the DOE Geothermal Drill Bit Development Program. As you know, the tester and test results are described in detail in Terra Tek reports TR 79-84 and TR 80-98. All tests were run with 100 psi nitrogen and 142.5 pounds of block load. H-30 blocks and S-25 rings were used; the tests were 5,000 revolutions at 70 RPM, i.e., 69 minutes, per ASTM D2714-68. The "Load Capacity" is 142.5 pounds divided by the wear scar area. Measurements are on the envelopes containing the test rings and blocks.

The coefficient of friction is the drag force divided by 142.5 pounds. Generally, the friction is higher in the early stages of the test, due to metal-to-metal wear. The friction generally stabilizes once a lubricant film is established. The peak coefficient of friction and the final coefficient are reported. The test results are as follows:

TEST NO.	LUBRICANT	TEMP. °F	LOAD CAPACITY KSI	COEFFICIENT OF FRICTION		COMMENTS
				PEAK	FINAL	
188	Mineral Oil	70-126	4.30	0.49	0.13	Calibration
189	GKS	590	8.46	0.24	0.20	High friction
190	MUR	600	6.22	0.23	0.14	Ruined journals
191	Pacer PLX-139	600	12.67	0.12	0.12	Very clean scar
192	Pacer Geobond	600	7.70	0.22	0.165	Galling
193	Pacer PLX-150	600	6.30	0.22	0.10	Deposits

The mineral oil test was run to checkout the machine, and is included as part of the setup. The 4.30 ksi capacity agreed quite well with the 4.1 ksi average established in previous tests.

Mr. Robert Evans
January 26, 1983
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All of the lubricants that you submitted for evaluation exceeded the 4.3 ksi test criterion which we established for the DOE program in 1978. This was based on four tests on a conventional journal bit lubricant at 100 psi and 75-118°F.

The GKS had high load capacity but also had high friction. MUR had relatively good friction characteristics, but the tester journals were ruined; these are enclosed. This may have been the result of an interaction between the silver plating on the journals and the copper in the MUR.

The Pacer Geobond load capacity was 7.7 ksi, which is less than the 9.0 ksi average for 10 tests reported previously in TR 80-98, but within the normal spread for these tests. Pacer Geobond was used in a series of tests on 8-3/4 inch bits here at the DRL in 1981 as part of the DOE program. These were air-drilling tests at temperature. These bits had silver plated bushings in the journals, and thermocouples were installed in each journal and at each thrust face. The journals ran hot: whereas the conventional bit ran 40-50°F over ambient at 25,000 pounds, the Geobond bits ran 100-200°F hotter, with excursions to 400-500°F, and brief transients to 1,000°F. Interestingly, there was no measurable wear or evidence of metal-metal contact on the entire bearing system for any of these bits using Geobond grease.

It was because of these drilling tests that I suggested re-running Geobond grease in the lubricant tester: coefficient of friction was not recorded on the previous 10 tests. As I expected, the factor for the Geobond was somewhat high: a good lubricant should be in the vicinity of 0.12, not 0.165. There was also one small galling scar which we had not seen in previous tests. This might be due to a defect in the block.

Pacer PLX-139 produced the highest load capacity of any elastomer-compatible lubricant in the history of the tester (although one non-compatible lubricant reached 13.0 ksi; see TR 80-98). Furthermore, the wear scar was smooth and uniform, and the coefficient of friction was low. The final consistency and appearance of the lubricant was very similar to its original condition. Most significant, I believe, is the lack of high initial friction; metal-to-metal contact was obviously very minimal.

Pacer PLX-150 produced some unusual results: the final friction was the lowest of the six, but significant wear occurred, i.e., load capacity was only 6.3 ksi. The 0.10 coefficient of friction has only been seen once in the previous 187 tests, and that was on Mystic JT-6 (Cato Oil & Grease Manufacturing) which is probably not compatible with elastomers at temperature. The block for test 193 (PLX-150) was examined under a 7-40X stereo-zoom microscope. Deposits of gold and silver colored metal are evident. The gold is in two bands in the scar, and the silver is in deposits at the edge

Mr. Robert Evans
January 26, 1983
Page three

where the ring is coming into the block. The lubricant produces very objectionable odors at 600°F; I suspect that the sulphur-based agents responsible for the odor would also attack elastomers and cause embrittlement or softening.

In all tests, a small amount of lubricant escapes out onto the drive shaft, and generally bakes onto this 500-600°F steel surface. The three Pacer products did produce some smoke when they leaked onto the shaft, but the remaining material was a grease very much like the original product. This residue was easily wiped off the shaft. This behavior may be favorable to the seal in geothermal air drilling such as the Geysers.

My choice would be PLX-139. However, it must be remembered that this tester, like all others, cannot totally predict how the grease will perform in a bit. The GKS, MUR or PLX-150 might also work.

Preparation for your seal tests are nearly complete, and we should be ready to test when the seals are received.

Sincerely,

Robert R. Hendrickson
Senior Research Engineer

RRH:sp

DRILLING RESEARCH LABORATORY

March 30, 1983

Mr. Robert Evans
P. O. Box 45874
Dallas, TX 75235

Dear Bob:

Your first two high-temperature seal life tests were run during the week of March 21st. In this letter, I will briefly summarize the work we have done to date. I have enclosed the failed seals from these tests.

Test Conditions

In our conversation of March 9th, we finalized the test conditions as follows:

- o Pacer PLX-139 grease below seal.
- o Water and sand above seal.
- o ± 0.007 inches of radial "jog".
- o 0 to 0.010 inches of axial runout.
- o Schedule
 - 0 - 2 hours: 300°F, no rotation, 0 pressure differential
 - 2 - 4 hours: 300°F, 90 RPM, + 15 psi pressure differential
 - 4 - 6 hours: 300°F, 90 RPM, - 15 psi pressure differential
 - 6-100 hours: 300°F, 90 RPM, + 15 psi pressure differential
- o Monitor seal each hour, record grease volume and correct pressures as required. Test will be terminated when lubricant volume has increased or decreased by 12 cc (0.75 cubic inches).

Seal Test Machine Modifications

In order to provide the test conditions, several modifications were made to the machine:

1. Accumulators were added to the vessel and the lubricant pressurization system, and a precision gas regulator was used to control the seal differential pressure.
2. A sight-tube and bellows were added to monitor lubricant volume.
3. The pressure/displacement relationship of the lubricant bellows was measured. This made it possible to maintain a constant differential pressure across the seal regardless of lubricant volume.
4. The main stroke cam was modified to minimize axial runout.

Seal Carrier Modifications

Difficulties were encountered in assembling the seal to the disk and the hub. The seal was first soaked in Pacer DHT-90G oil at 200°F. This will generally soften most elastomers, but it did not appreciably soften the HTR seal. The seal was first installed on the disk, with some difficulty due to the seal edges hanging up at the disk edges. Next, the seal was stretched over the center hub. At this point, one seal lip tore from the outer edge inward to the I.D. When rotated, the seal tended to slip primarily on the hub instead of the disk.

The center hub was modified to facilitate seal installation and to clamp the seal to the hub. One end of the hub was ground down to the minimum diameter of the seal. The removed material was replaced by a steel ring which was sized to axially compress the seal 0.008 inches; the ring's outside diameter was 2.300 inches. A 2.300 inch O.D. flange was also added to the hub so that the seal would be compressed uniformly (hub diameter is 2.200 inches).

Seal Testing

A preliminary test was run on a standard O-ring seal to check the test system for proper operation. The standard seal held + 15 psid at 300 °F and 90 RPM for over an hour and the test was terminated.

Next, the jog motion was checked, including measurement of the pin clearance; jog was set to ± 0.007 inches. The axial shaft position was measured and a spacer was made to provide correct axial alignment of the seal/hub to the seal disk.

In Test Number 1, the seal soaked for two hours at 300°F, with no differential pressure. Rotation was then started at 90RPM, and a positive 15 psid lubricant pressure was applied. Within five minutes, all grease had leaked from the system and the test was terminated.

Upon disassembly, a large quantity of grease was observed in the sand reservoir above the seal (note that no sand was used in Tests 1 or 2). It was also observed that the upper seal lip was completely severed from the seal body at the point where it was clamped by the hub.

On March 22nd, we discussed these results and agreed to the following changes: The disk would be radiused to 0.030 inches to avoid any possibility of damaging the sealing surface during mounting; the axial runout would be reduced as far as possible by putting ten balls in the stroke cam instead of one; and, the axial alignment would be rechecked.

Prior to Test Number 2, the cam was loaded with 10 balls, the shaft position was remeasured, and a new spacer was made to achieve correct alignment. The new spacer was 0.009" thicker than the one used in Test Number 1. This is to be expected, since the net effect of using 10 balls is to keep the shaft in the full-down position. Seal installation was much easier with the full radius (0.030 inches) on the disk I.D.

Page Three
Mr. Robert Evans
March 30, 1983

Test Number 2 was run on March 23rd. The seal was soaked for two hours at 300°F with + 15 psid on the lubricant, and no leakage was observed. At two hours, rotation was initiated at 90 RPM, and gradual leakage was observed. At 12 minutes of rotation, the pressure was increased to + 30 psi in an attempt to seal the leakage. After 59 minutes of rotation (including the 12 minutes at + 15 psid) all of the grease (12 cc) had leaked out and the test was terminated. No sand was used in Test Number 2. Upon disassembly, no wear or damage was observed.

On March 24th, we discussed these results and agreed that new, improved seals are needed. You will investigate having Viton seals made using the existing mold, and will supply us with these seals within 3-4 weeks.

We expect to run your two lubricant tests on PLX-139, using the hard-metal blocks and beryllium-copper rings, the week of April 4th.

We look forward to resuming your seal test program; and hope that it will be soon.

Sincerely,

Robert R. Hendrickson
Sr. Research Engineer

RRH/mf

Enclosures

DRILLING RESEARCH LABORATORY

June 20, 1983

Mr. Robert Evans
P. O. Box 45874
Dallas, TX 75235

Dear Bob:

Enclosed are the results of the seal life test on your Viton slotted oval seal. Also enclosed are lubricants and test parts from lubricant tests 219 and 220.

The seal was tested under the following conditions:

Temperature	400°F
Soak time	2 hours
Sand	None
Pressure	500 psi
Differential Pressure	None - would not hold
Jog	± 0.007 inches
Axial Stroke	± 0.003 inches or less
Axial Position	Within 0.005 inches of alignment
Rotary Speed	90 RPM
Total Run Time	20 hours

The seal would not hold differential pressure, and leaked at a rate of several cc's per minute when we attempted to apply + 15 psi differential pressure.

Per your instructions, the test was continued in order to evaluate surface wear on the elastomeric sealing surfaces. On May 11th, I phoned you, and you decided to terminate the test; the seal experienced 2 hours of "soak" and 18 hours of rotation.

This concludes your lubricant and seal test program, and all failed parts have been returned to you. I have retained the three remaining seal rings and collar sets for any further seal testing that you may request.

It has been a pleasure working with you on the program, and we look forward to serving you again.

Sincerely,

Robert R. Hendrickson
Sr. Research Engineer

RRH/mf

Enclosure

"C" Seal

8 HLS. .228 DIA.
THRU. EQUA-SPACED ON
A 3.125 DIA. B.C.

SEAL CARRIER PLATE
4340 STL. H.T. R/C 45-48
2 REQ'D

8 HLS. .228 DIA.
THRU. EQUA-SPACED ON
A 3.125 DIA. B.C.

SEAL DISK
4340 STL. H.T. R/C 45-48

TEST BITS (2)
BEING CRATED FOR
SHIPMENT

BIT JOURNAL WITH
CALIPER SEAL IN
PLACE

ROOM TEMPERATURE
SEAL TEST FIXTURE

CALIPER SEAL TEST

FIXTURE

- A Seal Collar
- B Seal Carrier Plate
Upper and Lower
- C Seal Disc
- D Sealing Element

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