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CONOSEAL BAR-X SEAL TESTS

by

J. M. Edmiston
Fluid Flow Laboratory
Experimental Engineering Department

MASTER

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Approved by:

E. A. DeZubay

E. A. DeZubay, Manager
Fluid Flow Laboratory

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ABSTRACT

On the NRX-A reactors the instrument ports are sealed by a Bar-X seal. Damage to the ports, which are part of the pressure vessel, required machining on the pressure vessel. A new design, using a Marman flanged piece to house the Bar-X seal port separate from the pressure vessel, was proposed. The test program was to determine the torque required to seal and the ability of each seal to hold during thermal shock.

The Bar-X seal did not leak as in previous test programs, but after cold shock the Marman flange Conoseal gasket sealed marginally at ambient temperature.

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I. INTRODUCTION

These tests are to prove a new sealing configuration that would facilitate repairing damaged sealing surfaces in the instrumentation ports (possibly for NRX-A5).

Previous tests,^{1,2,3} on Bar-X seals in reactor pressure vessel instrument ports, indicated that a Bar-X seal with a maximum loading nut torque of 220 ft-lb_f will seal adequately. If a seal port is damaged or oversize, and does not seal, the torque may have to be increased to obtain a seal. If it is not possible to seal by increasing the torque, then the port would have to be reworked in the field which is a difficult operation. To overcome this difficult operation, a separate cap has been designed with the port built into it. This seal test fixture is shown in Figure 4 and the Marman flange is shown in Figures 5, 6 and 7.

These tests were requested on Reactor Design Work Request Number 41:41:55-4W.

II. EXPERIMENTAL EQUIPMENT

A. Test Fixture

The test fixture, as shown on Figures 4 through 7, consists of an aluminum block that represents the pressure vessel and contains half of the Marman flange, a stainless steel cover for the high pressure plenum, a Marman flanged cap containing the instrumentation port, a seal block simulating the instrumentation block, the Marman flange clamp ring, the Bar-X seal nut and the stainless steel, low pressure, cover. The drawings listed in Appendix B describe the fixture in greater detail.

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1. WANL-TME-722, "Proof Tests for the Bar-X and K-Seals"
 2. WANL-TME-970, "Bar-X Seal Test in Oversize Port"
 3. WANL-TME-1035, "Aluminum Bar-X Seal Test"

B. Test Method

The test flow loop is shown on Figures 1 through 3.

The fixture, less the outlet plenum, was checked with the inlet plenum pressurized with helium and the outlet of the seal covered with water and the appearance of bubbles indicated leakage. The fixture was then installed in the flow loop. After purging with helium, the inlet plenum was pressurized with hydrogen from a gas bottle through a pressure regulator. Leakage was measured by detecting a change in the pressure and the temperature of a fixed volume. This fixed volume included the discharge plenum, the manometer, the pressure gauge, and interconnecting lines. At the completion of the test the hydrogen was vented to atmosphere and the system purged with helium again before disassembly of the test fixture from the loop.

From ambient to stable cryogenic conditions required only immersing the fixture in the liquid nitrogen bath for 25 minutes or until agitation of the nitrogen ceased. Warm-up to room temperature required heating the fixture with hot water or electric heaters. It required at least one hour for the fixture to stabilize at room temperature.

The fixtures with two parallel leakage paths required examination of the Marman flange and Bar-X seal areas by a Vacuum Engineering Company MS-9 mass spectrometer leak detector. With the fixture pressurized with helium, a sniffing tube attachment is connected to the leak detector and is used to probe the fixture to locate the precise location of the leak.

C. Data Obtained

During the test period a record was made of:

Marman flange clamp ring torque

Bar-X seal nut torque

Barometric pressure

Test preparation.

The following readings were recorded every 10 minutes for half an hour at each temperature:

Time

Inlet gauge pressure

Outlet gauge pressure

Outlet manometer reading

Ambient temperature

Fixture ambient temperature

Any pertinent notes.

III. CALCULATIONS

The established maximum permissible hydrogen leakage rate from the reactor to the surrounding area was previously established as 10^{-2} std cc/sec/in of seal diameter. Since this assembly is to be compared to a Bar-X seal assembly in a pressure vessel port; i. e., no Marman flange, the Bar-X seal leakage allowance would control. For this seal the figure would be 2.020×10^{-2} std cc/sec, based on the Bar-X seal external diameter. It was decided, as in previous tests, the change in pressure in the fixed volume of the outlet plenum, etc., would be measured.

The temperature throughout this volume of gas is constant and the leakage rate is small; therefore, the process is isothermal. Here the perfect gas law can be applied:

$$PV = \frac{m R_o T}{144 M} \quad (1)$$

where

P = static pressure in (psia)

V = volume in ft^3

m = mass (lb_m) in volume V

R_o = universal gas constant is $1545 \frac{\text{ft lb}_f}{\text{lb mole } ^\circ\text{R}}$

M = molecular weight of hydrogen is $2.016 \text{ lb}_m/\text{lb mole}$

T = temperature in degrees Rankine

but since

$$m = W t \quad (2)$$

where

W = mass flow per unit time (lb_m/sec)

t = time (t) required to obtain mass (m) for flow rate (W)
(seconds)

Equation (1) can be written as

$$PV = \frac{W R_o T t}{144 M}$$

or

$$(P_2 - P_1) V = \frac{W R_o T (t_2 - t_1)}{144 M}$$

rearranged we get

$$\Delta P = \frac{W R_o T (\Delta t)}{144 M V} \quad (3)$$

where

$(P_2 - P_1), \Delta P$ = maximum allowable pressure rise in the leakage plenum (lb_f/in^2)

$(t_2 - t_1), \Delta t$ = period over which the pressure rise is measured (seconds)

V = leakage plenum volume. This includes the volume of the pressure lines to gauges and to vent valve (ft^3)

M = molecular weight of hydrogen is $2.016 \text{ lb}_m/\text{lb mole}$

R_o = universal gas constant is $1545 \frac{\text{ft lb}_f}{\text{lb mole } ^\circ\text{R}}$

T = temperature in $^\circ\text{R}$, the process is assumed to be isothermal, hence the temperature in the seal discharge plenum is assumed to be that of the seal inlet plenum which, in turn, is assumed to be that of the fluid surrounding the test fixture. The surrounding fluid is ambient air or liquid nitrogen.

W = maximum permissible hydrogen leakage rate (lb_m/sec)

With the use of Equation (3), the maximum allowable pressure rise will be calculated for the cryogenic and ambient temperature cases. The values of the parameters are as follows:

V = the leakage volume of Bar-X seal test fixture is approximately 0.0236 ft^3

W = maximum permissible leakage flow based on a 2.020-inch seal diameter ($3.740 \times 10^{-9} \text{ lb}_m/\text{sec}$)

$$R_o = 1545 \frac{\text{ft lb}_f}{\text{lb mole } ^\circ\text{R}}$$

t = for one hour test period (3600 seconds)

T = 140°R for cryogenic temperature case
540°R for ambient temperature case

Hence for the cryogenic case, the maximum allowable change in pressure with time is:

$$\Delta P = 0.853'' \text{ Hg/hr}$$

(This assumes that the entire measured volume is at 140°F and thus is a conservative figure. Most of the volume is at this temperature.)

and for the ambient case, the maximum allowable change in pressure with time is:

$$\Delta P = 3.23'' \text{ Hg/hr}$$

IV. RESULTS AND DISCUSSION OF THEIR SIGNIFICANCE

Refer to Table I for the summary used in this discussion. The initial tests indicated that the two seals did not leak at ambient temperature on the first cycle but that a high leak rate occurred at cryogenic conditions. The higher leak rate of cryogenic conditions is as experienced in the previous tests.^{1,2,3}

At this point with parallel seals it was decided to check the leakage source on a mass spectrometer leak detector with a sniffer. The result was that the Bar-X seal did not leak and the Conoseal in the Marman flange did.

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1. WANL-TME-722, "Proof Tests for the Bar-X and K-Seals"
 2. WANL-TME-970, "Bar-X Seal Test in Oversize Port"
 3. WANL-TME-1035, "Aluminum Bar-X Seal Test"

The Conoseal appeared damaged and was replaced before further testing.

On the next test series the seal leaked less at cryogenic conditions than at ambient temperature contrary to previous tests mentioned above. A recheck on the mass spectrometer leak detector disclosed a bad leak at the Marman flange - so bad that it saturated the leak detector.

It was concluded that the combination of an aluminum Conoseal with a stainless steel Marman flanged cover, with temperature cycling considering the different thermal expansions, would cause the seal to be less effective.

At this time the aluminum Marman flanged cover and a new aluminum Conoseal was incorporated into the test fixture. The results that followed on the next five cycles were that the leak rate was not always greater at ambient temperature than at cryogenic conditions. This would indicate that the Conoseal may have changed its seating during temperature alternations. Leakage exceeded the limit allowable, but by such a small margin that it could possibly be considered an acceptable seal.

V. CONCLUSIONS

The Bar-X seal is satisfactory, but the use of a parallel seal could not better the sealability of the Bar-X seal by itself.

The aluminum Conoseal in good condition with either an aluminum or stainless steel Marman flanged cover can seal within specifications if considered by itself. A less adequate Bar-X seal coupled with the same Conoseal might not leak within the allowable value if compared with a Bar-X seal in a reactor pressure vessel port. If in compromise, an additional leakage allowance is made for the Marman flange then the allowable leakage rate would perhaps be high enough to make the combination acceptable.

The condition of the aluminum Conoseal on disassembly indicate that they could not be used more than once.

VI. RECOMMENDATIONS

Consideration could be given to the use of stainless steel Conoseals particularly with a stainless steel Marman flanged cover to permit repeated assembly.

The Marman flange clamping ring is of a light weight spring-type material that will yield enough at higher pressure differentials to permit leakage through the seal. It is recommended that a heavier walled clamping ring be employed in this application; the heavier ring would resist spreading of the clamped flanges, and prohibit leakage.

TABLE I

CONOSEAL BAR-X SEAL TESTING SUMMARY

Test Description	Gas	Bar-X Seal Torque ft-lb	Temperature	Inlet Pressure psig	Remarks
<u>Stainless Steel Marman Flange</u>					
*Leak Check With Water Covering Outlet Plenum	Helium	120	Ambient	250	High leak rate.
		160	Ambient	775	No leak for 10 minutes.
		175	Ambient	806	No leak.
Cold Shock	----	175	Cryogenic	0	Preparation for test.
Flow Test	Hydrogen	175	Ambient	720	No leak for 30 minutes.
	Hydrogen	175	Cryogenic	720	Leak rate 1.2 times allowable value on last 10 minutes of 30 minute test and increasing.
Leak Check	Helium	175	Ambient	800	No leak for 10 minutes.
Leak Check on Mass Spectrometer Leak Detector MS-9	Helium	175	Cryogenic	600	Leakage around Marman flange. Bar-X seal did not leak. Conoseal in- spected and replaced.
Leak Check	Helium	175	Ambient	800	No leak for 10 minutes.
Cold Shock	----	175	Cryogenic	0	Preparation for test.
Flow Test	Hydrogen	175	Ambient	800	Leak rate 0.186 times allowable over 30 minute period.
Flow Test	Hydrogen	175	Cryogenic	800	No leak.
Flow Test	Hydrogen	175	Ambient	800	Leak rate 0.37 time allow- able over 30 minute period.

*Stainless steel Marman flange cover with 90 in-lb torque on clamp ring.

TABLE I (CONTINUED)

Test Description	Gas	Bar-X Seal Torque ft-lb	Temperature	Inlet Pressure psig	Remarks
Flow Test	Hydrogen	175	Cryogenic	800	No leak.
Leak Test on MS-9	Helium	175	Ambient	75	Leakage around Marman flange.
<u>Aluminum Marman Flange</u>					
**Cold Shock	----	175	Cryogenic	0	----
Flow Test	Hydrogen	175	Ambient	820	Leak rate 0.28 times allowable.
Flow Test	Hydrogen	175	Cryogenic	820	Leak rate 0.70 times allowable.
Flow Test	Hydrogen	175	Ambient	820	Leak rate 1.08 times allowable.
Flow Test	Hydrogen	175	Cryogenic	820	Leak rate 0.35 times allowable.
Flow Test	Hydrogen	175	Ambient	820	Leak rate 0.186 times allowable.
Flow Test	Hydrogen	175	Cryogenic	840	No leak in 30 minutes.
Flow Test	Hydrogen	175	Ambient	810	Leak rate 0.57 times allowable.
Flow Test	Hydrogen	175	Cryogenic	825	Leak rate 1.05 times allowable.
Flow Test	Hydrogen	175	Ambient	815	Leak rate 0.124 times allowable.
Flow Test	Hydrogen	175	Cryogenic	830	Leak rate 0.47 times allowable.
Leak Check on MS-9	Helium	175	Ambient	200	Leakage around Marman flange.

**Replaced steel flange with aluminum flange with 90 in-lb torque on clamp ring.

Figure 1

Schematic of Seal Test Facility

Figure 2

Bar-X Seal Test Arrangement From Interior of Cell

Figure 3

Bar-X Seal Test Arrangement Through Cell Window

Figure 4

Assembled Bar-X Seal Fixture With Internal Marman Flange

Figure 5

Bar-X Seal Test Fixture Assembly With Marmar Flange

Figure 6

Bar-X Seal Test Fixture With Marman Flange

Figure 7

Marman Flanges

APPENDIX A

TEST RECORD SHEET

The following Test Record Sheets describe the test in detail.

<u>Test Record Sheet</u>	<u>Date</u>
K1706773	6/9/64
	6/10/64
	6/11/64
K1706784	7/10/64
K1706785	7/10/64
K1706786	7/10/64
K1706787	7/10/64
K1706788	7/13/64
K1706789	7/14/64
K1535112	7/23/64
K1535114	8/4/64
K1535115	8/4/64
	8/6/64
K1535121	8/11/64
	8/13/64
K1535126	9/1/64
	9/8/64
K1535127	9/9/64
	9/10/64
K1535128	9/8/64
K1535129	9/9/64
	9/10/64
	9/11/64

APPENDIX B

HARDWARE

The hardware and fixtures were supplied by Reactor Mechanical Design. The following is a list of supplied parts.

<u>Quantity</u>	<u>Drawing</u>	<u>Item</u>
1	945 C 479 H01 Rev. -	Nut
1	963 B 921 H01 Rev. -	Pin
3	963 B 320 H01 Rev. A	Bar-X Seal
1	945 C 702 H01 Rev. -	Ring
2	937 J 110 Item 9	Seal Block
1	937 J 110 Item 7	Locking Cup
1	937 J 110 Item 8	Locking Cup
2	937 J 110 Item 10	Adapter
1	937 J 110 Item 11	Spacer
1	937 J 110 Item 12	Spacer
1	937 J 110 Item 13	Pin
1	937 J 110 Item 16	Adapter
1	710 J 404 Rev. -	Test Fixture
1	945 B 186 H01 Rev. -	Washer
1	945 B 187 H01 Rev. -	Pin
1	945 C 505 Rev. -	Coupling
1	946 C 105 H01 Rev. -	Gasket
50	*Size 261	"O" Ring

<u>Quantity</u>	<u>Drawing</u>	<u>Item</u>
50	*Size 240	"O" Ring
12	0.625-11 UNC x 3.00 lg	Bolt
8	0.500-13 UNC x 2.25 lg	Bolt

*Precision Rubber Products Company. Uniform size number.