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WRITTEN BY J. Charles*		ATOMICS INTERNATIONAL A Division of North American Aviation, Inc. TECHNICAL DATA RECORD	TDR NO. 4334
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UNIT Mechanical Equipment			SUB-ACCT. 4925
APPROVED BY: (SUPERVISOR)		PROGRAM	TWR 5263
OTHER		PROJECT	DATE August 19, 1959
			PAGE 1 OF 18

TO: **A. Miller***

COPIES TO: D. Casey*	W. Hallett*	T. Ricci*
B. Colmery	J. Leppard	H. Sletten*
J. Cochran*	J. Owens	
J. Droher	C. Petlak*	
R. Dickenson	M. Mueller	
J. Greenleaf	M. Noe*	

SUBJECT: **HNPF Process Tube - Grid Seal**

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I STATEMENT OF PROBLEM

Determine the characteristics of a piston ring seal assembly (C. Lee Cook Co. #AAI-33504-1) and evaluate its suitability for use as the HNPF process tube-grid plate seal.

Design specifications require that the rings satisfy the following requirements:

(1) Have a sodium leakage rate of less than 0.198¹ percent of the coolant flow rate through an average channel.

(2) Have a useful life of not less than 10,000 cycles² over a 3-inch stroke in 625° sodium.

(3) Have the ability to withstand without damage 25 cycles² over a 3-inch stroke in 1000°F sodium.

II SUMMARY OF RESULTS AND RECOMMENDATIONS

A. Results

1. A maximum leak rate of 0.08% was measured on two assemblies prior to cycling one assembly in sodium.

2a. A maximum leak rate of 0.14% was observed after the one assembly was subjected to 10,000 cycles (560 hrs) in 625°F sodium.

2b. A maximum leak rate of 0.07% was exhibited by this same assembly after exposure to an additional 25 cycles ($\frac{1}{2}$ hr) in 1000°F sodium.

3. Examination of the rings and bore subsequent to the 10,000 cycles test revealed some vertical scoring of both the rings and bore tube (Figures 1 and 2). The maximum depth of the damaged areas in the bore tube was 0.001 inch.

4. Washing the ring assembly, after exposure to sodium, with steam, water, and alcohol did not remove the sodium from behind the rings (Figure 2).

5. Figures 3 and 4 present curves of the leak rates vs. pressure difference across the seals.

6. Figures 5 and 6 present the leak rates as a percentage of flow in an average channel vs. percent of rated reactor power.

B. Recommendations

1. Use piston ring assemblies as the sliding seals required for the HNPf process tube-grid plates seals.

2. Make additional tests with 4-in. diameter seals.

a. Evaluate spring-loaded piston ring seals.

b. Evaluate nitrided bore tubes.

3. Determine what effect the sodium remaining behind the rings after washing will have on the fuel handling operations.

III. METHOD USED, EQUIPMENT, DISCUSSION, SAMPLE CALCULATIONS

A. Method Used

It had been thought that, by using the conversion methods described by Welsh, ambient water could be used as the test fluid for the leak rate measurements, and that the data could subsequently be converted to sodium. The first data obtained using 60°F water indicated that the leak rates increased with increasing pressure until a difference of approximately 8 psi was reached. At pressure differentials greater than 8 psi the leak rates decreased with increasing pressure. This same characteristic was later observed with 180°F water (Figure 3). Evidently, at 8 psi the rings began to seat against the bottom side of the ring groove decreasing the leakage area. The method described by Welsh requires that either the configuration of the seal be the same for the test medium (water) and the reactor coolant (sodium) or that the size ratio of the two configurations be known. Because the ratio of the

pressure differentials required for the 60°F water and for the 607°F sodium is 10:1 (Fig. 7), and the configuration of the seal varies an unknown amount with pressure changes this method could not be used with 60°F water.

The leak rate measurements reported herein were made using 180±1°F water as the test medium. At this water temperature the ratio of the pressure differentials for 607°F sodium to the water is unity (Fig. 7), and therefore the seal configuration is identical for the two fluids (ignoring the minor size difference due thermal expansion). The sodium leak rate is 95% of the water rate (Fig. 8).

Two identical 4½-in. dia. piston ring seal assemblies were evaluated. Water leak rate measurements were made on both sets prior to cycling the first set in sodium. To represent reactor operating conditions the first set was subjected to a life test of 10,034 cycles (560 hrs) over a 3-in. stroke in 625°F sodium. The assembly was cycled for 16 hrs/day and was maintained at the test temperature at all times. The leak measurements were then repeated. Under a scram condition whereby the secondary pumps are stopped and the primary pumps continue to operate, the process tube-grid plate seals would be exposed to 1000°F sodium for a short time. To determine the effect of this unusual condition on the piston ring assembly the first set was cycled 25 times (½ hr. at 1000°F - 2½ hrs. above 600°F) over a 3-in. stroke in 1000°F sodium.

B. Description of Equipment

Figure 9 is a sketch of the 17-4PH stainless steel piston rings (AAI-33404-1), the type 304 stainless steel pistons, and the type 304 stainless steel bore tubes used in these tests. The pistons contained two grooves in which two concentric rings per groove were used; the 4.500-in. O.D. outside rings included a special locking feature (Fig. 9). All critical dimensions were according to the ring manufacturer's* recommendations.

Sketches of the equipment used for the leak rate measurements and for both the 625°F and 1000°F sodium cycling tests are shown in Fig. 10 and 11 respectively. The same piston and bore tube (Fig. 9) were used in both the water and sodium tests. In the cycling tests, the piston assembly was pneumatically driven; the cycle time and stroke length were controlled by a combination of limit switches, time delay switches, and a 4-way valve.

C. Discussion

The HNPF fuel elements are supported in the top shield and extend down into the grid plate located below the core. The sodium coolant flows

*Airtomic Products Division of C. Lee Cook Co., Division of Dover Corp.

from a plenum below this grid plate up through each process tube, which is part of the fuel element assembly, to the top plenum. To prevent an appreciable percentage of the coolant flow from being by-passed at the grid plate, a seal between the process tube and grid plate is required. To compensate for differential growth between the fuel element assemblies and the reactor vessel these seals must be capable of motion.

The permissible leak rate was specified as 100 #/hr per fuel channel at full rated power.¹ This leak rate is 0.198 percent of the rated flow in an average channel with the reactor at full power. The specification is interpreted to mean that the allowable leak rate is 0.198 percent of an average coolant channel flow at all power levels.

The percentage leak rate data presented in Figures 5 and 6 are conservative and could be lowered by 20 percent. The design pressure drop across the core is 17 psi at a rated full power coolant flow of 14.07 lbs/sec in an average channel; these data (Fig. 5 and 6) are based on this differential. Results of hydraulic experiments performed on the 19 rod U-Mo element, indicates that the drop across the core can be expected to be less than 17 psi; an estimate of this pressure differential is 12 psi.⁴ Therefore, the data can be reduced to 84 percent ($12/17$) of that presented. In addition, the data presented in Figures 3, 4, 5, and 6 are the measured water rates. Actual 607°F sodium rates would be 95 percent of these 180°F water values (Fig. 8). Therefore, the data in Figures 5 and 6 could be reduced to 80 percent ($.84 \times .95$) of that presented.

Upon completion of the 10,034 cycle test the ring assembly was steam cleaned and then soaked in water for two days. This cleaning operation failed to remove the sodium from behind the rings (Fig. 1). The residual sodium kept the rings in an expanded position making their removal from the piston difficult. Sodium remaining behind the rings might cause difficulty in the fuel handling cask when a fuel element is placed in the travel position. In this position the ring assembly mates with a bore forming a seal for the cask coolant gas similar to the seals in the grid plate. The frozen sodium behind the rings might prevent proper compression of the rings or result in ring breakage.

During the course of the testing reported herein the design size of the process tube-grid seals was reduced from 4.500-inches to 4.000-inches. The change was made to eliminate the possibility of the ring breakage during removal of the fuel elements from the core as this smaller dimension minimizes the likelihood of the rings catching under the bottom heads of the moderator assemblies. While it is probable that 4.000-inch rings will perform as well as the 4.500-inch rings further testing to verify their adequacy is planned. In addition, a spring loaded piston ring assembly will be tested. The springs are designed to force the rings against the grooves at low pressure differentials and thus minimize change in sealing conditions with pressure change.

At the conclusion of the 625°F sodium cycling test both the rings and bore tube exhibited some vertical scoring (Fig. 1 and 2). The damage on the rings was minor, but the depth of the damage areas in the bore tube was as much as 0.001 inches. This damage adversely affected the sealing characteristics (0.14 percent maximum) of the assembly but not to the extent that the seal was inadequate. In conjunction with the 4.000-in. diameter seal tests it is planned to investigate the merits of nitrided bore tubes. It is expected that this surface treatment will be adequate protection for the bore tubes.

The leak rates demonstrated by the seal assembly subsequent to the 1000°F test were significantly smaller than the rates measured after the 625°F test (Fig. 3 and 5). This anomaly might be explained by assuming that the scoring damage found after the 625°F test was "healed" to some extent during the 1000°F test. If some of the material displaced from the surface of the bore tube flowed into the bore on either side of the score marks, the depth of the damage measured (reported by Inspection to be 0.001-in. maximum after the 625°F test) would have included this displaced material. Furthermore, if some of this displaced material was scraped or cut from the bore during the 1000°F test, improved sealing characteristics could be expected for the two following reasons:

(1) With the raised (displaced) material removed from the bore the mating fit between piston rings and bore around the full circumference of the rings would be improved.

(2) With the raised material removed the leakage area between rings and bore tube in the region of the damage would be decreased.

The explanation presented above tends to be verified by Inspection's report to the effect that while the actual depth of the damage (after 1000°F test) could not be determined it was less than 0.001-in. maximum.

D. Sample Calculations

The following sample calculations are for set #1 prior to sodium cycling. The applied gas pressure was 4 psi and the run duration was 10 minutes.

1. Change in Water Level During Run

$$\begin{aligned} h &= \frac{(W_t) (\sqrt{})}{454 A} \\ &= \frac{(1629) (28.55)}{454 \cdot 15.78} = 6.5 \text{ in.} \end{aligned}$$

2. Average Differential Pressure Sealed

$$\Delta P = P + \frac{1}{\sqrt{A}} (18 - \frac{h}{2})$$

$$= 4 + \frac{1}{28.55} (18 - 3.25) = 4.517 \text{ psi}$$

3. Percentage of Rated Power That ΔP Represents

$$p = 100 \sqrt{\frac{\Delta P}{17}}$$

$$= 100 \sqrt{\frac{4.517}{17}} = 51.6 \%$$

4. Rated Average Channel Flow Corresponding to ΔP

$$Q = (\frac{p}{100}) W$$

$$Q = (\frac{51.6}{100}) (382 \times 10^4) = 197.5 \times 10^4$$

5. Leak Rate as Percentage of Q

$$Q_L = \frac{W_t}{Q} \times 100$$

$$Q_L = \frac{1629}{197.5 \times 10^4} \times 100 = 0.0825\%$$

NOMENCLATURE

- h = Change in water level during run (in.)
 W_t = Water collected during 10-minute run (gm)
 A = Cross sectional area of water column above seal (in.)
 $\sqrt{A}$ = Specific volume of water at 180°F (in³/lb)
 P = Average sealed pressure (psi)
 P = Gas pressure applied above water (psi)
 L = Height of water column at start of run (in.)
 p = Percentage of rated power that ΔP represents (%)
 Q = Flow through an average channel in 10 minutes corresponding to ΔP . (gm)
 W = Rated full power flow through an average channel in 10 minutes (gm)

IV. REFERENCES AND APPENDICES

1. A.V.O. - H. Sletten to J. Greenleaf, Dated 5 May 1959,
"HNPF - Reactor Core Elements Rings Seal Leakage."
2. I.O.L. - A. Miller to Distribution, Dated 3 November, 1958,
"Test Conditions - Process Tube - Seal Test."
3. TDR No. 3128, "Converting Data from the Water Loop to Sodium."
R. D. Welsh.
4. Private Communication with S. Sudar on 4 August 1959.

Original data for this report are recorded in Laboratory Notebook
A016251.

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W. E. SEMI LOGARITHMIC 359 73
KEUFFEL & ESSER CO. MA IN U.S.A.
(L.S.) OF V. ONS.

359-14
10X10 TO THE CM.
KEUFFEL & ESSER CO.
MADE IN U.S.A.

LEAK RATE AS % OF AVERAGE CHANNEL FLOW RATE

FIGURE 5

REACTOR POWER AS PERCENT OF RATED POWER

K&E 10 X 10 TO THE CM. 359-14
KEUFFEL & ESSER CO. MADE IN U.S.A.

LEAK RATE AS % OF AVERAGE CHANNEL FLOW RATE

FIGURE 6

REACTOR POWER AS PERCENT OF RATED POWER

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MODEL NO

WEIGHT FLOW RATE CONVERSION H₂O TO 607°F NA

1/7/59

a.c. Muller

$$\frac{Q_{NA}}{Q_{H_2O}} = \frac{(W \cdot Y)_{NA}}{(W \cdot Y)_{H_2O}}$$

$$\frac{Q_{NA}(W \cdot Y) / (W \cdot Y)_{H_2O}}{Q_{H_2O}(W \cdot Y) / (W \cdot Y)_{H_2O}}$$

FIGURE 8

RING MAT'L. ARMCO 17-4 PH
HARDNESS--ROCK C-30 MIN.
FREE GAP - $\frac{3}{16}$ TO $\frac{3}{8}$ NOT HOOKED
RING FLAT WITHIN .0002
MAX. FREE DIA. = 4.550
WITH JOINT HOOKED

SCALE $\frac{1}{2}$

SCALE $\frac{1}{2}$

FIGURE 9

RING SEAL - PISTON AND BORE TUBE

WATER LEAK RATE TEST

SCALE $\frac{1}{4}$ " = 1"

FIGURE 11

SODIUM CYCLING TEST

SCALE $\frac{1}{4}" = 1"$