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F. O. Streck

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APPROVED BY: (SUPERVISOR) <i>B.H. Colmery, Jr.</i>		PROGRAM HNPF	TWR	
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TO: **R. W. Atz**

COPIES TO:

C. J. Brous	C. Gerber
J. C. Cochran	L. E. Glasgow
B. H. Colmery*	W. J. Hallett
R. Cygan	L. E. Manners
G. E. Deegan*	F. Perez
R. W. Dickinson	

SUBJECT:

Performance Test of a Two-Coolant-Region Sodium Pump Shaft Freeze-Seal*

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I STATEMENT OF PROBLEM

The operation of the freeze-seal type sodium pump requires a shaft freeze-seal capable of retaining sodium. A prototype two-coolant-region freeze seal for application on HNPF sodium pumps had been designed and constructed. It was required that it be tested under environmental conditions to determine its operating characteristics and sodium retaining capabilities.

II SUMMARY OF RESULTS AND RECOMMENDATIONS

A. Results*

The seal is capable of retaining sodium at 600°F with the shaft rotating at 1000 rpm. The sodium to gas differential pressure was 15 psi.

1. Gas Leakage

At normal seal temperatures a ΔP of 15 psig can be impressed across the seal without significant leakage of gas or sodium from the sodium side. Shaft speeds of from

* This report covers work performed on freeze seal test stand number 1 and completed several months ago. It is being published for completeness and will be followed by a separate report on two series of tests on freeze seal test stand number 2 completed in May 1959.

zero to 1000 rpm have had no effect upon gas leakage from the sodium side of the seal. Gas inleakage will occur to the sodium side of the seal during normal operation when a differential pressure of 3 psig or greater is impressed across the seal. Definite rates, however, were not established. Due to lack of driving power to the shaft (which would be stalled if the seal were kept too cool) it could not be established whether lower seal temperatures would prevent an in-leak of gas during operation.

2. Motor Load

Motor load is linear and decreases with increasing sodium temperature. Approximately 1.4 kilowatts are required to drive the shaft at 1000 rpm with the sodium at 500°F. (See Figure 4) A comparison of the frozen seal power requirements with an unwetted seal motor load is shown in Figure 6.

3. Seal Cooling Load

At a sodium temperature of 500°F the total seal cooling load is 3.1 kilowatts. It can be seen from Figure 5 that the seal cooling load is directly proportional to the sodium temperature.

4. Seal Temperature

Temperature measured across the seal decreased generally exponentially from the inner to the outer end of the seal (See Figure 1 and 2.) Reverse tetralin flow in the lower region of the seal produced lower average temperatures throughout the seal.

5. Sodium Extrusion

During this test about 6 in.³ of sodium were found to have extruded along the pump shaft into the gas filled space above the seal (See photo 7508-5410A). This leakage occurred at various times and under variable conditions so that the cause of this loss was not established.

B. Recommendations

This test did not closely simulate the conditions to be encountered in the freeze seal pump. It is recommended that further tests be performed on this type seal in the second freeze seal test stand. The thermocouples should be

re-arranged to measure more accurately the location of the molten sodium interface.

III METHOD USED, DESCRIPTION OF EQUIPMENT, SAMPLE CALCULATIONS

In a sodium freeze-seal for a sodium-pump shaft, leakage of liquid sodium is prevented by frozen sodium. A cooling system is required to freeze the sodium in the seal and to keep it from being melted by heat conducted from liquid sodium.

The type of seal tested had two tetralin cooling loops mounted side-by-side on the pump shaft. Principal advantages of the two-region seals over single-region seals are that location of the liquid/solid interface can be more accurately determined and more precisely controlled. The two-region seal is therefore more flexible and more reliable. Since all connections are made outside the seal, it is unlikely that tetralin leaks could occur at joints in the vicinity of the seal.

Satisfactory operation of two-region type freeze seals has previously been demonstrated on 2-inch solid pump shafts. The HNPF pump shaft is 5 inches in diameter and is hollow to a diameter of 4 inches. The purpose of the tests reported herein is (1) to determine seal operating conditions, temperature gradients across the seal, location of the liquid/solid sodium interface, seal cooling requirements, seal friction loss, and (2) to indicate that a two-region shaft freeze seal will operate satisfactorily on a 5-inch hollow, pump shaft.

A. Methods

Tests were run with the shaft at 0 through 1000 rpm, with tetralin flow rates of 4.75 to 9.49 lb. per. min. through each region of the seal, and with bulk liquid sodium temperatures of 500, 550, 575 and 600°F. Corresponding HNPF design values are 835 rpm and 1000°F.

Temperatures at selected points on the exterior seal coolant channel walls (See Figure 3.) were measured with thermocouples and the temperature gradients plotted. (See Figure 2) The location of the liquid/solid interface was taken as that point at which the temperature was 208°F.

Seal cooling requirements were determined by measuring coolant inlet and outlet temperatures and coolant flow rates and computing the amount of heat removed. At the temperatures encountered during the tests, the heat capacity and specific gravity of tetralin are almost constant and no correction was made for these changes.

Pump shaft speeds were measured with a stroboscope. Pump

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power was measured with a wattmeter.

The ability of the seal to retain sodium was determined by visual observation through a heat-resistant glass viewing port. (See photograph 7508-5410A)

B. Description of Equipment

The equipment used in these tests consist of a two-coolant-region freeze seal and a 5-inch diameter hollow shaft. In the lower coolant region tetralin flows through 6 turns of 1/2-inch x 0.35-inch wall tubing coiled around a perforated sleeve and contained within a cylindrical housing. In the upper coolant region of the seal tetralin flows through a hollow flange concentric around the shaft. The 5-inch shaft was hollow along the portion which passed through the seal. The shaft wall thickness was 0.250-inches at the hollow section. The radial clearance between the shaft and the seal was 0.0625-inches. (See photographs 7508-5402 A and B.)

1. Description of Test Rig

The test rig consisted of a static sodium pot heated by tubular heaters, a surge tank which could be pressurized to impress a differential pressure across the seal, a stuffing box which contained the seal, and a bearing housing which supported the shaft and its driver. The driver was a 15 HP direct current variable speed motor.

2. Description of Instruments

- (a) All speed measurements were made with a Strobotac measuring device. This instrument incorporates a neon light which can be adjusted to flash at a predetermined rate. When the light is directed upon the rotating shaft coupling and it appears to stop, the speed is equal to the number of flashes per minute. Accuracy of this device is $\pm 1\%$.
- (b) Seal sodium temperature measurements were made with chromel-alumel stainless steel sheathed thermocouples and were recorded on an L & N Speed-omax 6-point recorder. The probable error in the thermocouples is $\pm 4^\circ\text{F}$. The probable error in the recorder is 1/4 of 1% of full scale reading. Other temperature measurements were made with chromel-alumel glass-and-asbestos-insulated thermocouples. The temperatures were indicated on a Brown 24 point

indicator. Probable error of the thermocouple is $\pm 4^{\circ}\text{F}$. Probable error of the indicator is $1/4$ of 1% of full scale reading. Tetralin ΔT measurements were made, using chromel-alumel differential thermocouples connected to a slide-wire potentiometer. Probable error of thermocouple $\pm 4^{\circ}\text{F}$. Probable error the instrument $1/2$ of 1% of full scale.

Tetralin flow measurements were made using a Fisher-Porter variable area flowmeter. Probable error $\pm 1\%$ of full scale.

Motor ammeter and voltmeter data are accurate to $\pm 5\%$ of full scale.

SAMPLE CALCULATIONS

Cooling load lower seal

Assuming that all heat removed from the lower seal is removed by the flowing tetralin, the cooling load of the seal is given by,

$$Q = M \times C_p \times \Delta T$$

where,

- Q = Cooling load on lower seal region in BTU/min.
- M = Tetralin flow through lower seal region in lb./min.
- C_p = Specific heat of tetralin, in BTU/lb. = 0.40
- ΔT = Difference in tetralin inlet and outlet temperatures at lower seal region, in $^{\circ}\text{F}$.

from known data,

Flowrator full flow = 5.7 gpm (100%) and, tetralin weighs 8.06 lb/gallon at 95°F so, for a flowrator reading of 20%, the mass flow rate is $(0.20)(5.7)(8.06) = 9.2$ lb/min.

For the differential thermocouple used, a reading of 0.022 MV corresponds to a ΔT of 1°F .

Thus, for a differential thermocouple reading of 0.765 MV and a flowrator reading of 20% (observed at 450°F sodium temperature and 1000 rpm shaft speed)

$$Q = (9.2)(0.40)\left(\frac{.765}{0.022}\right) = 12800 \text{ BTU/min.}$$

$$= 2.25 \text{ KW}$$

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It can be seen from Figure 5 that the variation of the cooling load appears to be linear with sodium temperature. It can also be seen from the data below that the friction load of the seal varied with the shaft speed, but not with sodium temperature.

Friction Cooling Load of Seal

Speed rpm	1000	0
Na temperature °F	450	450
Tetralin flow lb./min. upper	9.49	9.49
Tetralin flow lb./min. lower	9.49	9.49
cooling load KW	2.93	1.525
	2.935 KW	1000 rpm
	1.525 KW	1000 rpm
	1.410 KW	friction load
Speed rpm	1000	0
Na temperature °F	500	500
Tetralin flow lb./min. upper	9.49	9.49
Tetralin flow lb./min. lower	9.49	9.49
Cooling load KW	3.02	1.605
	3.020 KW	1000 rpm
	1.605 KW	0 rpm
	1.415 KW	friction load

TEMPERATURE DISTRIBUTION ALONG SHAFT FREEZE SEAL

FIGURE 1

TEMPERATURE DISTRIBUTION ALONG SHAFT FREEZE SEAL
Reverse vs. Forward Flow

Symbol	Direction of Flow	Shaft Speed rpm	Both Regions Total Tetralin Flow lb/min
○	Reverse	1000	18.98
△	Forward	1000	18.98

Reverse Flow = Tetralin enters at bottom of seal tubing and leaves at top.

Forward Flow = Tetralin enters at top of seal tubing and leaves at bottom

FIGURE 2

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TWO REGION SHAFT FREEZE SEAL

MODEL NO.

FIG 3

Motor Load vs Sodium Temperature

Shaft Speed rpm - 1000

Tetralin Flow (Both Regions) #min - 18.98

FIGURE 4

TOTAL SEAL COOLING LOAD VS SODIUM TEMPERATURE

<u>Na Temp. °F</u>	<u>Total Tetralin Flow #/min.</u>	<u>Speed rpm</u>
410	18.98	1000
450	18.98	1000
500	18.98	1000
560	18.98	1000

FIGURE 5

10X10 1/2" 359-11
 KUPPERLINS INC.

Motor Load vs Shaft Speed

Total
Tetralin Flow # min

△	565°F	18.98
○	555°F	18.98
+	550°F	18.98
×	500°F	18.98

FIGURE 6

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