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Westinghouse Astronuclear Laboratory

TEST SERIES FFL-6

ORIFICE TO ELEMENT SEALING DEVELOPMENT

(Title Unclassified)

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ORIFICE TO ELEMENT SEALING DEVELOPMENT

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ABSTRACT

A seal is required between a multiple hole graphite element and the stainless steel orifice inserted therein. The objective is to develop a satisfactory seal that would have increased temperature capabilities in a radiation environment over that of the present Silastic RTV-891.

Two gasket configurations were flow-tested under a pressure differential at ambient temperature and compared for sealing effectiveness against the present material.

A common gasket assembly for the entire element face and individual gaskets for each orifice were 12 and 66 percent as effective as the Silastic seal.

Neither gasket configuration provided any distinct advantage over the present method. Other avenues will have to be investigated.

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I. INTRODUCTION

A. Background

Dow Corning "Silastic RTV-891" rubber, an electrical insulating adhesive sealant rubber, will withstand temperatures up to 390°F for extended periods and can be used for shorter periods at higher temperatures. Squeezed from the collapsible tube it cures at room temperature and 50 percent relative humidity tack-free in about one hour and cures to a depth of 1/8 inch in 24 hours.* It bonds well to both the graphite fuel element used in this application and to the stainless steel orifices inserted in the element holes.

Installation of the orifices is achieved by wetting a small diameter needle with sealant from a tube and coating the orifices on the surface that will mate to the graphite element. The orifice is held in a fixture handle, then the orifice is rotated in a hole in the graphite rod to coat the element. The orifice is removed, recoated as above, and reinstalled. The sealant is allowed to cure. A leakage test on the rod with a full complement of orifices determines the acceptability of the seal.

B. Justification of Performance of Work

Operational limitations imposed by the present orifice-to-element seals on the Westinghouse Astronuclear Laboratory (WANL) reactor can be relieved by developing a satisfactory substitute sealing method that will increase the time and temperature capabilities in this area of the reactor and retain the

* Dow Corning Electrical Materials brochure Form No. 01-024.

effectiveness of the Silastic. A test program must be pursued to evaluate the capability of new sealing configurations.

C. Problem Statement

Due to the temperature limitations of the present orifice-to-element sealant, an effective pneumatically-equivalent sealing configuration must be developed. The new sealing configuration must be compatible with the radiation environment and must increase the temperature capabilities of the orifice-to-element seal so that it does not impose reactor design and/or operational limitations.

II. EXPERIMENTAL EQUIPMENT

A. Design

The test fixture is shown in Figure 1. It consists of a 3/4-inch pipe section with a 3/4 by 1 inch reducing bushing screwed at one end and a 3/4-inch pipe coupling screwed at the other. A ring was brazed internally into the pipe coupling to serve as a mounting seat for the test specimen. The pipe coupling was reduced in steps to a 1/4-inch tubing fitting. A 1/4-inch tube-to-pipe fitting was brazed to the side of the 3/4-inch pipe section. A 1-inch pipe cap was screwed to the bushing. Through the top of the pipe cap a stud was threaded into a nut brazed on the underside of the pipe cap. A suitable O-ring sealed the stud to the pipe cap interface.

The fixture was designed to permit ready integration of the fixture into an existing test loop. The pipe cap removal allowed access for placement

of the test piece. The holding screw or stud was employed to apply load to a plate that retained a soft rubber gasket. The side tubing fitting was for gas inflow and the axial or bottom tubing fitting was for gas outflow.

The graphite portion of the test specimen was attached and sealed to the fixture with epoxy cement no more than 1/4 inch up the side of the test specimen. The orifices were mounted on the top side of the specimen. The flow was down through the orifice face into the test specimen.

B. The Test Loop

The test loop is shown in Figures 2, 3, and 4. The test loop consists of a helium supply for purging the system before and after a test, a relief valve to limit the maximum pressure to 900 psig, and a hydrogen supply for seal testing. Mounted between each gas bottle and the test fixture are:

1. A gauge to indicate bottle pressure
2. A pressure regulator
3. A gauge to indicate regulated pressure
4. A hand valve to open and close the supply to the fixture
5. A solenoid valve to open and close the supply to the fixture

Two gauges, protected by snubbers and solenoid valves, indicate inlet and outlet pressures of the test fixture. A thermocouple was mounted to measure gas temperature at the exit of the test fixture. A bypass loop around the test fixture permitted stabilizing the pressure across the fixture. A mercury manometer with valves on both sides (legs) was also connected to the outlet line from the test

fixture to measure small changes in outlet pressure. A calibrated sonic orifice of suitable size was connected to the outlet line to measure flow where the rate of change of outlet pressure would be in excess of 3 in. Hg/sec for the test volume.

C. Test Method

After the system was purged with helium, the system was pressurized with hydrogen. Initially, the bypass was opened to provide a common pressure across the test fixture plenums, then the bypass was closed and the outlet plenum pressure was reduced by the amount of the differential pressure desired. One leg of the manometer was opened to the outlet plenum pressure, then the manometer crossover valve was closed and the stop clock was started simultaneously. After a change of 36 in. Hg on the manometer (its full range), the manometer crossover valve was opened and the stop clock stopped simultaneously. The temperature, pressures, and time on stop clock were recorded for each test sequence described above. Each test sequence was repeated twice.

If the manometer mercury column height changed full range in less than 12 seconds, then a 0.025-inch diameter orifice in 1/4-inch tubing, vented to atmosphere, was substituted for the manometer as shown in Figure 4. The pressure in the downstream plenum of the test fixture was regulated by a remotely operated valve upstream of the sonic orifice. The pressure and temperature upstream of the sonic orifice, and pressures and temperatures related to the test fixture, were recorded for each test condition. The sonic orifice was used with most tests.

D. Test Configurations

Two test configurations as presently defined (per Westinghouse Drawing No. 710J197) are shown in Figures 5 and 6. They are respectively:

1. Orifice sealing by an individual gasket per orifice. Orifices and gaskets are held in place by a metal plate with approximately the same outer boundaries as the test specimen.

2. Orifice sealing by a single gasket common to all orifices, but otherwise much the same as above design.

A third configuration tested was the presently applied design similar to Figure 7. No hold-down bolt is required for this configuration since the Silastic is also an adhesive.

For reference purposes, the test configurations were each compared to two extreme modifications. The worst sealing condition conceivable is no gasket or sealant in the above assemblies, but with the hardware assembled and the related specimen mounted in the fixture as for the appropriate test configuration above. The best sealing condition conceivable is a test specimen and the hardware with the orifice face covered with a soft rubber gasket and a metal hold-down plate. The hold-down plate would be loaded with the fixture hold-down stud or screws.

The worst sealing condition (i.e., no gasket) is a base from which to measure the effectiveness or the requirement for seals other than contact at the interfaces. A poorly applied, incomplete, or porous seal may have greater

leakage than a good interface contact metal-to-graphite. The best sealing condition, in turn, should seal the orifice-to-specimen interface completely so that the only flow would be due to the porosity of the element section and the ineffectiveness of the mounting seal of a test specimen to the test fixture.

E. Data Required

The program called for evaluation of the effectiveness of each seal configuration at ambient temperature initially using gaseous hydrogen. The final design selection is to be tested at both cryogenic and operating conditions with the environmental conditions to be supplied when required.

The test data reported should be leak rates with an upstream pressure of 675 psig with various downstream pressures: 625, 635, 645, 655, and 665 psig.

III. CALCULATIONS

For flow rates that were low enough to measure as a change on a mercury manometer, the following relationship¹ was used:

$$\frac{\Delta M}{\Delta t} = 9 \times 10^{-4} \frac{\Delta P}{\Delta t} \frac{1}{T}$$

where

$$\frac{\Delta M}{\Delta t} \quad \text{is change in mass of gas contained with respect to}$$

time at fixture exit, lb/sec

1. Refer to Appendix A for derivation of equation.

$\frac{\Delta P}{\Delta t}$ is change in pressure of gas contained with respect to
time at fixture exit, in. Hg/sec

T is temperature of gas contained at fixture exit, °R

For flow rates that require the use of a sonic orifice, the following
relationship ² was employed

$$\dot{m} = C_o P_o / (T_o)^{1/2}$$

where

$\dot{m}$ is the flow rate, lb/sec

C_o is the orifice coefficient

P_o is the absolute upstream orifice pressure, lb/in²

T_o is the absolute gas temperature at orifice, °R

IV. RESULTS AND THEIR SIGNIFICANCE

The test data is tabulated in Table 1, pages 10 and 11, for each of the
three basic test configurations.

Figure 8 is a graphic representation of the effectiveness of the
sealing configurations. The common-gasket, individual gasket, and Silastic 891
configurations are respectively 17, 66, and 100 percent effective on a compara-
tive basis.

2. Refer to Appendix B for derivation of equations.

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V. CONCLUSIONS

The common gasket is ineffective because the rigidity of the gasket material does not lend itself to conformation to the surface of the element particularly if the element is chipped or has surface voids. The individual gasket, though of the same rigid material, is superior to the common gasket because each gasket has only to seal local surface irregularities and is independent of the action of any other orifice gasket.

A low Durometer gasket material is not feasible because the limited area of gasket coverage requires high strength to prevent tearing on formation or application of the gasket.

The Silastic forms a good seal because it can flow to fill surface irregularities. This configuration allows independent seating of the orifice since a hold-down plate is not required that could misalign an orifice to its proper location.

The hold-down bolt threaded into the element provides a leakage path that would require sealing. (In these tests to separate this problem from that of the gasket the center hole was blocked with a sealant.)

VI. RECOMMENDATIONS

Neither gasket has the capacity to correct for element surface irregularities, therefore a sealant that is capable of flowing into these irregularities is required.

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Investigation into a substitute for Silastic of similar nature or a brazing operation both using the same simple configuration now used seems to be the better approach.

The use of a combination of a gasket configuration with a surface preparation on the graphite, that is to fill irregularities with a metal coating followed by surface grinding or with a thin coating of a high temperature cement, seem to be secondary compromises. Some objection has been raised to the difficulty of obtaining a good surface bond between the metal and the graphite; this is also the problem that arises in brazing. The thin coating of cement with a gasket would permit use of adhesives somewhat permeable in a heavy application. This approach increases complexity.

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TABLE 1
ORIFICE SEAL LEAKAGE - INDIVIDUAL GASKET
 $\text{lb/sec} \times 10^6$

Pressure Drop psid	Configuration					
	Without Gasket		With Gasket		Soft Rubber Gasket	
	A	B	A	B	A	B
50	1348	952	466.5	307.0	11.10	4.81
40	1201	866	420.2	282.0	9.86	4.15
30	974	736	360.2	248.0	7.40	3.65
20	748	614	270.3	184.8	5.55	3.17
10	546	438	170.3	156.2	2.42	1.92

ORIFICE SEAL LEAKAGE - COMMON GASKET
 $\text{lb/sec} \times 10^6$

Pressure Drop psid	Configuration					
	Without Gasket		With Gasket		Soft Rubber Gasket	
	C	D	C	D	C	D
50	1825	1502	1488	1193	11.10	4.81
40	1565	1222	1362	1052	9.86	4.15
30	1325	1072	1167	884	7.40	3.65
20	1120	866	968	746	5.55	3.17
10	640	606	479	452	2.42	1.92

TABLE 1 - (Contd)
ORIFICE SEAL LEAKAGE - SILASTIC BONDED
lb/sec x 10⁶

Pressure Drop psid	Configuration								
	Without Sealant			With Sealant			Soft Rubber Gasket		
	E	F	G	E	F	G	E	F	G
50	428	466	331	.390	.274	.390	.404	.322	.368
40	388	424	296	.328	.233	.320	.318	.256	.299
30	341	371	261	.268	.162	.230	.242	.187	.219
20	280	310	215	.161	.107	.156	.154	.120	.139
10	212	211	151	.061	.058	.069	.064	.064	.062

Figure 1

ORIFICE TO ELEMENT SEAL TEST FIXTURE

Figure 2

SEAL TEST PANEL THROUGH CELL WINDOW

Figure 3
SEAL TEST PANEL

Figure 4

SCHEMATIC OF SEAL TEST FACILITY

Figure 5

INDIVIDUAL GASKET ORIFICE SEALING

Figure 6

COMMON GASKET ORIFICE SEALING

PRESENT METHOD OF SEALING - FFL-6 ORIFICE-TO-ELEMENT SEAL DEVELOPMENT

Figure 7

SILASTIC BOND ORIFICE SEALING

ORIFICE SEALING EFFECTIVENESS
 GAS: HYDROGEN
 INLET CONDITIONS: 675 PSIG
 AMBIENT

$$\text{SEALING EFFECTIVENESS} = \frac{(\text{NO SEAL FLOW} - \text{SEAL FLOW}) (100)}{\text{NO SEAL FLOW} - \text{RUBBER GASKET FLOW}}$$

Figure 8 - SEALING EFFECTIVENESS VERSUS PRESSURE DROP

APPENDIX A

Purpose

Determination of the leakage rate in terms of rate of pressure change.

Procedure

By dead ending the outlet plenum, i.e., close the vent and bypass valves and opening the valves to the manometer, the volume trapped will experience a change in pressure and temperature according to the Perfect Gas Laws.

$$\frac{\Delta P}{\Delta t} V = \frac{\Delta M}{\Delta t} RT$$

where

$\frac{\Delta P}{\Delta t}$ is change in pressure with respect to time, lb/in²/sec

V is trapped volume, ft³

$\frac{\Delta M}{\Delta t}$ is change in mass of gas with respect to time, lb/sec

R is hydrogen gas constant, equal to 5.32 $\frac{\text{ft}^4}{\text{in}^2 \text{ sec}^2 \text{ } ^\circ\text{R}}$

T is temperature in trapped volume, °R

APPENDIX A - (Contd)

To solve $\frac{\Delta M}{\Delta t}$

$$\frac{\Delta M}{\Delta t} = \frac{\Delta P}{\Delta t} \frac{V}{RT}$$

so

$$\frac{\Delta M}{\Delta t} = \left(\frac{\Delta P \text{ in. Hg}}{\Delta t \text{ sec}} \right) \left(\frac{.4912 \text{ lb/in}^2}{1 \text{ in. Hg}} \right) \left(\frac{(.0097 \text{ std ft}^3)}{(T) (766)} \right)$$

V trapped volume is found from:

Volume of seal panel exit side	=	190 cm ³
Volume of 1/4" flexible hose (98 1/2" long)	=	79 cm ³
Volume of fixture outlet plenum	=	7 cm ³
Total	=	276 cm ³
(16.39 cm ³ = 1 in ³)	=	16.85 in ³
(1728 in ³ = 1 ft ³)	=	.00975 ft ³

$$\frac{\Delta M}{\Delta t} = \frac{(.4912) (.00975)}{(5.32)} \frac{\Delta P}{\Delta t} \frac{1}{T}$$

$$\frac{\Delta M}{\Delta t} = 9 \times 10^{-4} \frac{\Delta P}{\Delta t} \frac{1}{T}$$

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APPENDIX B

Purpose

Determination of the leakage rate in terms of sonic orifice flow.

Procedure

A series of sonic flow orifices have been calibrated using a wet test meter, American Meter Co., Serial No. AL21.10496.

Using the basic relationship for orifices at sonic condition¹

$$\dot{m} = C_D A_o P_o \left[\left(\frac{g K}{R T_o} \right)^{2/(K+1)} \frac{(K+1)^{K/(K+1)}}{(K-1)^{1/(K+1)}} \right]^{\frac{1}{2}}$$

$\dot{m}$ is mass flow rate lb/sec

C_D is coefficient of discharge

A_o is area of orifice, in²

P_o is absolute upstream pressure lb/in²

g is gravitational constant 32.2 ft/sec²

K is specific heat ratio

R is gas constant for hydrogen is 766 ft/sec °R

T_o is absolute gas temperature at orifice, °R

-
1. Discharge Coefficients of Small Diameter Orifices and Flow Nozzles, Grace & Lapple ASME Transactions Volume 73 July 1951

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APPENDIX B - (Contd)

For a specific orifice and line size, orifice mounting configuration, temperature range, and gaseous medium, the above equation may be reduced to

$$\dot{m} = C_o P_o / (T_o)^{\frac{1}{2}}$$

where

$\dot{m}$ is flow rate lb/sec

C_o is orifice coefficient determined by calibration on
the wet test meter

P_o is absolute upstream orifice pressure lb/in²

T_o is absolute gas temperature at orifice °R

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