MASTER

Program: Cover Gas Seals
DOE Task: 26-Cover Gas Seal Components
Program Manager: R. W. Keaten
Reporting Period: Oct. - Dec. 1977
General Order: 09283
Project Manager: L. Baurmash
Category: HN-10-04-02.2
Subaccount: 14508, 15000, 18000 189a Number: SA026

DOE/SF/76026--T8

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I. PROJECT OBJECTIVES

The objectives of the Cover Gas Seal Components Test Program are to develop and demonstrate the performance of commercial and custom-designed head region cavity seals for LMFBR reactors, to develop and evaluate advanced seal concepts capable of achieving improvement in radioactive gas containment and seal temperature-life capabilities, and to establish operational safety margins for head region seals for nominal and extraordinary LMFBR plant conditions.

During FY 1977 the CRBRP sodium dip seal configuration performance characteristics were determined and the seal demonstrated to meet system requirements. Current activities include verifying the acceptability of CRBRP head region inflatable elastomer seal manufacturers, developing the technology to improve static inflatable seal design, and determining the ultimate temperature capabilities of several elastomer seal materials.

II. MAJOR ACCOMPLISHMENTS DURING REPORT PERIOD

A. CRBRP SODIUM DIP SEAL

This activity was completed in FY 1977 and a report, N707TR230003, issued.

B. CRBRP INFLATABLE SEAL VENDOR QUALIFICATION

All testing per Addendum 2 of DRS 32.06, plus additional tests to determine the effects of horizontal and vertical misalignments, has been completed on the first vendor qualification seals supplied by Seal Master Corp., Kent, Ohio. The seals were operated through ~64,000m (210,000 ft.) of travel,

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subjected to two 300h dwell-breakaway tests, and measured for static cross-seal leakage at specific intervals during the test sequence. Except for the over nominal pressure tests, all testing was conducted at 52°C (125°F) with seal inflation and buffer cavity pressures of 1.53×10^5 Pa (7.5 psig) and 1.08×10^5 Pa (1.0 psig) respectively.

Table 1 summarizes the drag results for all dynamic and dwell -breakaway tests.

TABLE I
CRBRP Seal Vendor 1, Drag Summary

Test Parameter	Drag N/m (LB/ft)	
	First 64,000m	Second 64,000m
Dynamic Drag		
Nominal	250 (15)	230 (14)
Maximum	410 (24.5)	269 (16.4)
Minimum	208 (12.7)	154 (9.4)
Break Away ^①		
Initial	1000 (60)	833 (50)
After 1/4 Rev.	467 (28)	467 (28)
After 5 Rev.	333 (20)	383 (23)
Stabilized	250 (15)	233 (14)

^① measured after 300 hr static dwell

Measurements made throughout the test have shown a consistently excessive gas leakage across the seals. Table II shows the results of the post-test series which are typical of previous tests.

TABLE II
Post-Test Static Leakage Rates

Test	Pressure: $\text{Pa} \times 10^{-5}$ (psig)		Leak Rates SCCM	
	Inflation	Buffer	Measured	Allowable
Nominal Design (7.5 psig inflation pressure)	1.53 (7.5)	1.08 (1.0)	1.35	0.05
Maximum Design (35.0 psig inflation pressure)	3.43 (35)	2.32 (19)	3.0	^①

^① No specified maximum

A series of special tests were conducted to determine the effects of the 0.30 cm (0.12 in.) horizontal and vertical total indicated runout (T.I.R.) imposed on the seal to duplicate design conditions and are summarized in Table III below. Vertical T.I.R. is established by determining the vertical position of the seal blade to provide line-to-line contact between the seal and blade and then tilting the track to obtain a .15 cm (.06 in.) interference and a .15 cm (.06 in.) gap 180° apart on the seal circumference. The midpoints (at 90° and 270°) remain at the line-to-line contact condition. Test #2 (Table III) was conducted with the nominal .30 cm T.I.R. but the reference zero point was a .15 cm (.06 in) seal-to-blade interference rather than line-to-line contact. Tests #4 and 5 (Table III) were similarly conducted with a .15 cm interference around the entire circumference.

TABLE III
Special Condition Leakage Rates

Test ID	T.I.R. cm (in)		Pressure: Pa x 10 ⁻⁵ (psig)	Leak Rate SCCM
	Vertical	Horizontal		
1	.30 (.12)	.30 (.12)	1.53 (7.5) 1.08 (1.0)	1.35
2	.30 (.12) ①	.30 (.12)	" "	0.43
3	0	.30 (.12)		0.2
4	0 ②	.30 (.12)	"	0.1
5	0 ②	.30 (.12)	2.04 (15.0)	0.05
6	.30 (.12)	0	1.53 (15.0)	0.07
7	.30 (.12)	0	2.04 (15.0)	0.04
8	0	0	1.53 (7.5) 1.08 (1.0)	0.05

① test run with .15 cm seal-blade reference interference (nominal = line to-line contacts)

② test run with .15 cm uniform seal-blade interference (nominal = line-to-line contacts)

Dynamic leakage tests have consistently shown a peak leakage once per revolution. The phenomenon was present on all previous seal tests (including tests on the B. F. Goodrich seals) and is the consequence of a 0.03 cm (0.14 in.) T.I.R. in the test fixture due to offset of the center of table rotation. The above static leakage tests were conducted with the seal oriented to the point of minimum offset to remove any effect of the eccentricity.

All of the data, results, and conclusions will be incorporated into a final test report, currently in preparation.

The qualification seals from the second vendor are not expected prior to January 1978. A firm delivery date has not been established.

C. B. STATIC INFLATABLE SEAL DEVELOPMENT

All elastomer test bladders and ASTM slabs have been received for the 1) stainless steel mesh reinforced and 2) aluminum foil gas permeation barrier specimens. Three of the bladders with the foil permeation barrier have some small air pockets and possibly localized delamination between the elastomer and foil. The fourth bladder, delivered later, is of better quality with no significant wrinkling.

The steel mesh reinforced bladders are of substantially poorer quality with numerous wrinkles across the contacting face of the bladder. Stiffness of the steel mesh is the main problem. All bladders are leak tight and inflate to an acceptable contour when pressurized.

A test fixture drawing has been prepared and test fixtures will be fabricated during January. Testing will be initiated in February and will consist of two primary functions: 1) pressure cycling to determine the structural integrity of the specimens and 2) gas leakage tests to determine the ability of the bladders to retard gas permeation.

D. HIGH TEMPERATURE SEAL DEGRADATION

No activity this quarter. Test plans will be prepared and testing initiated during the second quarter of FY 1978.

III. IMPACT ON LMFBR PROGRAMS

Elastomer and sodium dip seals developed under this program provide the primary radioactive gas containment barrier for LMFBR systems. Advances in sealing efficiencies and seal thermal capabilities will increase reactor safety margins and relax thermal restraints in seal containing machines.

IV. NEXT REPORT PERIOD ACTIVITIES

The final report on the Seal Qualification Tests for the first seal vendor will be issued. Testing will be initiated on the steel mesh and aluminum foil containing test bladders. High temperature seal degradation tests will be initiated.

Program:	Cover Gas Seals		
DOE Task:	26-Fuel Handling Subcomponent Development		
Program Manager:	R. W. Keaten	Project Manager:	L. Baurmash
Reporting Period:	Oct. - Dec. 1977	Category:	HN-10-04-02.2
General Order:	09283	Subaccount:	32000
			189a Number: SA032

Principal Investigators: O. P. Steele III, R. M. Oliva

I. PROJECT OBJECTIVES

The objective of this program is: 1) to determine the environmental conditions that significantly contribute to the carryover of sodium on lifting devices, and 2) to establish the influence of the various parameters on the quantity of sodium transported by components removed from the sodium pool.

II. PROGRESS DURING THE REPORTING PERIOD

AI was authorized to proceed with this task the latter part of July 1977. A Test Plan (N707TP830008) and a Test Procedure (N707DTP830012) were prepared and issued August 5 and 8, 1977, respectively. Test articles were prepared in accordance with Table 1 to provide varied and representative material samples for evaluation in sodium. Four groups of the various materials were tested and the preliminary results were discussed in AI-DOE-13208.

Eight additional groups of test articles were subjected to the conditions of simulated reactor refueling cycles this report period. The conditions of test are noted in Table 2. The primary variable in these tests was the O₂ content in the argon cover gas and efforts were and are being concentrated on determining the effect that the O₂ has on the wetting of the various test materials and/or on the carryover of sodium to the chain hoist components.

Wetting Tests

Nine of the tests noted on Table 2 were cycling tests in which the load chain and test articles were cycled in and out of 400⁰F sodium following an

NOTE: SHEARED EDGES
ARE ACCEPTABLE

TABLE I
TEST SPECIMEN MATERIALS

TOTAL No. REQUIRED	MATERIAL	THICKNESS	SURFACE PREPARATION	MATERIAL SPECIFICATION	IDENTIFICATION	
					LETTER	NUMBER
40	1020 Steel	.050	Cleaned	Ultrasonic Dowclene Bath	A	1 to 40
40	↓	↓	Oxide Finish	MIL-C-13924, CLASS I	B	↓
40	↓	↓	Chrome Plated	AI SPEC N001A0109001, Type II, Class A	C	↓
40	↓	↓	Tin Plated	MIL-T-10727, Type I, .2-.4 Mil	D	↓
40	↓	.035	Nickel Plated	QQ-N-290, Class 2, .2 - .4 Mils	E	↓
40	304 SS	↓	Cleaned	Ultrasonic Dowclene Bath	F	↓
40	304 SS	↓	Oxide Finish	MIL-C-13924, CLASS 2	G	↓
40	301 SS	↓	Cleaned	AMS 5519F	H	↓
40	Inconel	↓	Cleaned	AMS 5596B	I	↓
40	Steel	3/8 CHAIN	*	AISI 4615	—	↓
40	Stainless St.	↓	Cleaned	↓	S	↓
40	Steel	↓	Chrome Plated	AISI 4615, QQC320, Class 2a	C	↓

*Burnished, tested in 400F Sodium, alcohol cleaned, ultrasonic Dowclene bath.

TABLE II

Test Group	Sodium Temp. °F	Nominal Avg. Cover Gas Temp. °F	Nominal Cover Gas Press Inches H ₂ O	Immersion/Withdrawal Speed Ft/Min	Cover Gas Moisture Content ppm	Cover Gas O ₂ Content ppm	Sodium O ₂ Content ppm	Test Duration * Yrs.	Degree of Wetting (Estimated) %	Comments
1	400	120	1-3	10.3	~ 1	~ 6	7.9,9.8	2	↑ See Table 2 ↓	Sodium Soak Test only; no cycling
2	400	120	1-3	10.3	~ 1	~ 46 [†]	8.7,8.7	1		
3	400	120	1-3	--	~ 1	~ 6	8.7,12.0	>72Hrs		
4	400	120	1-3	10.3	~ 1	~ 46	12.0,13.3	1		Chain removed for cleaning. 6 oz. Na on chain, 4 oz. on hoist components
5	400	120	1-3	10.3	~ 1	~ 25	8.6	1		
6	400	120	1-3	10.3	~ 1	~ 47 [†]	8.7	1		
7	400	120	1-3	10.3	~ 1	~ 25	8.7,9.1	1		
8	400	120	1-3	10.3	~ 1	~ 10	8.7,9.1	.6		
8A	400	120	1-3	--	~ 1	~ 6	9.1,11.9	306Hrs	↓	Chain jammed, removed for cleaning. 6 oz. on chain; 4 oz. on other hoist components. Sodium soak test only; no cycling Chain jammed Sodium soak only
9	400	120	1-3	10.3	~ 1	4 to 13	9.0, 13.0	5.8		
9A	400	120	1-3	--	~ 1	4 to 13	9.0, 13.0	468 hrs.		
10	400	100	1-3	1 to 2	> 1	~ 1	4.3,4.7	5	↓	

*Years of simulated refueling cycles

†Spiked argon with 46 ppm was quickly gettered; consequently, the 46 ppm O₂ gas was applied only at the upper region of the chamber where the specimens rested during the 5 minutes dwell.

†During the 2nd year of test, one-fourth of test was run with 100 ppm O₂ purge gas applied to chamber

immersion-withdrawal sequence that simulated a typical refueling cycle. This sequence resulted in representative sodium and cover gas exposure durations and subjected the test articles to about 800 minutes of sodium soak (320 immersions of about 2.5 minutes each) plus a total of about 2000 minutes of cover gas exposure per year of simulated reactor refueling cycles. The environmental conditions of each test are noted in Table 2.

The results of the tests are summarized in Table 3 and show the estimated degree of wetting, based on visual examination. While no trends are obvious from this table as to the exact mechanism causing wetting, it is clear that the exposure to the cover gas constituents is the major contributor. This is borne out by the fact that in eight of the nine cycling tests in and out of sodium, significant wetting occurred while in three tests (3, 8A and 9A) in which specimens were limited to sodium soaks, little or no wetting took place. This suggests, also, that the sodium O_2 content (in the ranges noted) at $400^{\circ}F$ makes no apparent contribution to the wetting.

Additional evidence that the wetting occurs as a result of cover gas exposure was obtained from a visual examination of the chain link specimens. In those instances when the chain link surfaces were well wetted, the links were frequently coupled with a characteristic wetted joint. When the joint was broken, however, the link to link contacting surfaces were found to have zero wetting. These regions of the links had diminished exposure to the cover gas due to exclusion by contact or by exclusion due to the sodium barrier at the joint.

It should be noted that the cover gas O_2 contents noted in Table 1 for the first eight cycling tests were not necessarily representative of the chamber's overall O_2 levels. Initial attempts to realize a uniform level of ~ 46 ppm O_2 , for example, in the cover gas met with failure because the oxygen was rapidly gettered by the sodium making accurate control virtually impossible. Also, this large quantity of O_2 soon resulted in a heavy layer of oxide on the sodium pool. Such a condition, if prolonged, could not be accommodated by the system's cold trap cleanup system. As a consequence spiked argon gas with the desired O_2 level was introduced into the upper end of the test chamber while the test articles rested in that region for the five minute dwell portion of the twenty minute refueling cycle.

TABLE III

Degree of Sodium Wetting - Estimated %

Material	Condition	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 8A	Test 9	Test 9A	Test 10
1020, Bare	"New" Specimens with with no previous sodium carryover test exposure ↓	50	95	*	98	100	92	100	98	*	100	*	70
1020, Oxide Coat		50	90	*	98	98	100	95	90	*	100	*	90
1020, Chrome Plated		60	95	*	100	98	100	95	98	*	100	*	90
1020, Tin Plated		100	100	75 [†]	100	100	50	80	98	25 [†]	100	*	40
1020, Nickel Plated		60	90	*	100	100	90	95	90	*	100	*	25
304, Bare		60	90	*	100	99	25	60	70	*	100	*	5
304, Oxide Coat		30	70	*	98	98	97	85	98	*	100	*	10
301, Bare		60	95	*	100	100	95	70	95	*	100	*	10
Inconel		50	80	*	95	100	40	40	95	*	100	*	15
Stainless Steel Chain		60	80	*	90	99	40	25	80	*	100 ^Δ	*	--
Chrome Plated 4615 Chain	Specimens previously subjected to sodium carryover tests, clean- ed in alcohol followed by ultrasonic Dowclene bath ↓	70	85	*	90	99	30	30	80	*	100 ^Δ	*	--
4615 Chain (Previously tested & cleaned)		50	75	*	90	99	60	30	80	*	100 ^Δ	*	--
1020, Bare		-	95	*	95	90	98	85	100	*	100	--	--
1020, Oxide Coat		-	90	*	95	98	95	95	98	*	100	--	--
1020, Chrome Plated		-	95	*	100	100	100	90	95	*	100	--	--
1020, Tin Plated		-	70	*	70	85	95	98	98	*	100	--	--
1020, Nickel Plated		-	90	*	95	98	95	95	98	*	100	--	--
304 Bare		-	50	*	90	100	100	50	98	*	100	--	--
304, Oxide Coat		-	90	*	95	90	95	60	95	*	100	--	--
301, Bare		-	65	*	95	99	98	90	90	*	100	--	--
Inconel		-	80	*	90	85	98	30	90	*	100	--	--
Stainless Steel Chain		-	--	--	--	--	40	--	85	*	--	--	--
Chrome Plated 4615 Chain		-	--	--	--	--	40	--	85	*	--	--	--
4615 Chain (Previously tested and cleaned)		-	--	--	--	--	20	--	85	*	--	--	--

* Test was a sodium soak; no cycling into the cover gas was conducted. Zero wetting; sodium droplets clinging to surface of some specimens (up to ~ 10% surface coverage).

† 100% wetting occurred on immersion; but under prolonged sodium exposure, surface turns "gold" (probably tin oxide) and wetting on this surface diminishes with time.

Δ Except in region of link contact.

At the same time, gas was introduced into the hoist chamber and chain fall to expose the chain links to the desired O_2 levels. During this period, the test articles were subjected to essentially the programmed O_2 levels; they were at something less than that during the remainder of the refueling cycle.

Most of the materials tested experienced significant wetting during the majority of the cycling tests conducted. The stainless materials and the Inconel coupon did not wet as readily or completely as the other materials. The tin plated specimens always wet upon the initial immersion in sodium. As time was accumulated, however, the tin plate appeared to undergo a change to a gold color (probably a tin oxide) and thereafter the degree of wetting diminished almost as a function of the test time.

The specimens which were tested in sodium/cover gas cycling tests, cleaned in alcohol followed by a Dowclene ultrasonic bath, and then retested in subsequent cycling tests demonstrated only a slight increase in the time required to wet. As a consequence, material surface condition resulting from a cleaning process does not appear to be a major determining factor as far as the wetting phenomena are concerned.

The use of the environmental test chamber was adequate to substantiate the fact that the cover gas O_2 content plays a prominent role in the wetting of materials cycled in and out of sodium. Unfortunately, it does not allow for an accurate determination of the precise O_2 content that marks the cross-over between wetting and not wetting because the very large volume of gas causes excessive variations in both control and measurement of the O_2 . Consequently, a small glove box was fitted with a sodium pot and a mechanism for cycling specimens in and out of the sodium (Figure 1). This new facility is now in use exploring the effects of cover gas O_2 under closely controlled atmosphere conditions.

Test #10 was the first test run under glove box conditions. The results on Table 3 show that with the cover gas O_2 levels in the range of about 1 ppm complete wetting does not occur. After 5 years of simulated reactor refueling cycles, some spotty surface deposits indicate that very limited partial wetting may have occurred (Figure 2). Subsequent tests will be run

FIGURE 1
GLOVE BOX TEST FACILITY

12-20-77

Rockwell International
Atoms International Division

9283-9

FIGURE 2

at higher cover gas O_2 levels in an attempt to ascertain the crossover point between wetting and not wetting.

Sodium Soak Tests

Tests 3, 8A, and 9A were soak tests of 72, 306, and > 972 hours, respectively, and were and are being run to see if prolonged exposure to 400°F sodium with 7-13 ppm O_2 will result in wetting of any of the material types being concurrently evaluated in the cycling tests. Except for the tin plated specimen which wets upon immersion, no significant wetting has taken place on any coupon.

Sodium Carryover

The hoist chain was removed at the end of the first four years of simulated testing (Tests 1, 2, and 4) for cleaning. Six ounces of sodium were removed from the chain and four additional ounces from the hoist components. After five more years (Tests 5, 6, 7, and 8), the chain jammed because of sodium buildup on the rear or take-up pocketwheel; and so another cleaning was performed. Again six and four ounces were removed from the chain and hoist components, respectively. The majority of sodium transported to and deposited on the hoist components was concentrated on the rear take-up assembly. Insignificant deposition occurred on the front or load wheel.

During Test #9, the hoist system jammed with 2.2 years of testing applied when an accumulation of sodium on the rear pocketwheel caused a load limit trip. Testing was continued to obtain additional wetting and carryover data after the sodium accumulation was removed from the hoist mechanism. A total of 5.8 years of testing was applied, and the test was terminated when a buildup of sodium on the rear pocketwheel again tripped the limit switch. A determination of the quantity of sodium deposits has not yet been made.

An evaluation of the sodium carryover to date shows that the molten sodium is carried in droplet form by the chain, which was immersed but not wetted, and then transferred to the colder hoist components where it freezes. In subsequent actions, it is scraped off and smeared onto cold chain links -- those which are never submerged in the sodium pool. Transfer and deposition accumulation eventually leads to excessive buildup on the chain and hoist components which causes chain disorientation and jamming. Such

conditions are obviously detrimental and point to the need for removal of excess sodium from the chain by a scraper or hot jet lance prior to the chain entering the hoist components. Removal by such a device in reactor operation would minimize or prevent buildup, reduce the amount of hoist region radioactive contamination, and yet still allow passage of a sufficient surface coating to provide an improved wear surface.

Conclusion

Based on test results to date, the following can be concluded:

1. The subject test materials and surface coatings will not wet in 400°F sodium having 7-13 ppm O₂.
2. Materials cycled in and out of 400°F sodium and cover gas (> 6ppm O₂) will wet.
3. Higher cover gas O₂ levels will increase the wetting rate.
4. Insertion/withdrawal speed does not appear to have a significant effect on wetting.
5. Surface films resulting from sodium removal/cleaning processes do not appear to impede wetting.
6. Sodium carryover appears to be a deposition/smear transfer process.
7. A method to limit excessive sodium transport is required (scraper, hot gas lance).
8. The number of test parameters and/or the range of variables can be reduced so as to minimize future testing and to allow the test program to concentrate on defining the effects of those conditions shown to be significant.

III. IMPACT ON LMFBR PROGRAMS

A determination of the conditions affecting sodium carryover is important because excessive carryover could alter and impair operation and performance of hoisting mechanisms and related components and would complicate the radiation shielding requirements for such items. Knowledge of the parameters will assist in establishing the means for carryover control.

IV. NEXT REPORT PERIOD ACTIVITIES

Sodium/cover gas cycling tests will continue in the glove box facility under accurate atmosphere control in an attempt to determine the cover gas O_2 content lower limit at which wetting of the various materials occurs. The hoist system in the environmental chamber will be cleaned of sodium and additional sodium carryover tests which will be run. Tests will be conducted to ascertain the effect of cover gas moisture content on both the wetting and carryover. Long term soak of specimens in $400^{\circ}F$ sodium (7-13 ppm) will be continued.