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AN
EXPERIMENTAL EVALUATION
OF A
SODIUM FREEZE VENT SYSTEM

AEC Research and Development Report

Atomics International
North American Rockwell

P.O. Box 309
Canoga Park, California 91304

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SODIUM FREEZE VENT SYSTEM

By

R. L. EICHELBERGER
R. L. McKISSON

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ABSTRACT

Two sodium freeze vents, designed in conformance with the Design Appendix of RDT E 4-13T, were tested over several ranges of temperature and sodium flow rate. Both vents were 27.5 in. long, and had annular widths of 0.055 in. between the outside of the internal heater and the ID of the outer pipe. In one vent, the pipe was provided with horizontal fins; in the other, the fins were omitted. With a vent temperature of 90°F, frozen sodium seals were successfully made with sodium velocity in the vent up to 30 ft/sec. For a given sodium flow rate, the seal location in the vent is most strongly influenced by vent temperature.

Application of 500-psi pressure on the sodium side of the seal did not cause creep in the vent. Also, in limited tests, in which oxygen contaminants were added both to the sodium and gas sides of a freeze seal, there was no effect on the ease of seal melting.

Raising the sodium temperature did result in an upward movement of the frozen plug when the seal was initially formed near the bottom of the vent. The motion occurred over an interval of a few milliseconds, at which time the seal reformed. For optimum stability, seals should be formed in the upper half of a freeze vent. As a further precaution against seal failure, the gas space above the seal should be small and closed.

The present work has resulted in recommendations for improving the RDT Standard.

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I. INTRODUCTION

For the proper operation of a pumped sodium system, it is desirable to eliminate gas pockets in the piping. Careful design can minimize the number of high points in a system, but there must inevitably remain some places in which gas will be trapped, as sodium rises in the system during filling. The purpose of the freeze vent is to allow the gas to escape as it is displaced by sodium as the system is filled, and then to form a positive seal of solid sodium when the gas is exhausted.

The recognition of the need for a freeze vent device resulted in the writing of an RDT Standard, RDT E 4-13T, "Freeze Vent for Sodium Service" (February 1971). The testing of a component, built following the principles laid down in the Standard, was carried out to give confidence in the use of freeze vents in the FFTF and subsequent FBR sodium systems.

II. FREEZE VENT DESIGN

The principle of operation of a freeze vent is that gas flows freely through it, but liquid sodium reaching the vent freezes and provides a positive seal which prevents the escape of sodium. By melting the sodium and allowing it to drain back into the system, the freeze vent may be re-used an indefinite number of times. Heat for the melting-out process is provided by a heater inside the vent, so that the outer diameter of the heater unit forms the inner wall of the vent annulus. The required length of the vent, as calculated from the Design Appendix of RDT E 4-13T, with a 100% margin for safety for reasonable operating conditions, was ~ 24 in. For the experimental system, a commercial heater with a diameter of 0.940 in. was available, in a length which provided 27.5 in. from the end of the heater to the centerline of the side arm. With 1-in. Schedule 40 stainless steel pipe (nominal ID, 1.049 in.) for the outer housing, the experimental freeze vent had a nominal annulus width of 0.055 in. The heater used was rated at 1500 w, 115 v.

Two freeze vents were tested, both with the same nominal dimensions. One vent had a bare 1-in. pipe for the housing; and the other had 2-in. diameter fins, 6 fins/in., welded to the housing. Welded fins of the design used could not be inspected to meet the code requirements of RDT E 4-13T, but were tested to determine the need for attaching fins to the vent. The experimental vent configuration is shown in Figure 1. Photographs of the finned and unfinned versions of the vent are shown in Figures 2 and 3. The details of the instrumentation and test stand are given in the next section.

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Figure 2. Finned Freeze Vent in Place on the Test Rig

Figure 3. Unfinned Freeze Vent in Place on the Test Rig

III. EXPERIMENTAL METHODS

A. APPARATUS AND INSTRUMENTATION

The experimental freeze vents were tested in a specially designed apparatus which enabled sodium to be introduced into the vent from the bottom, at various flow rates and temperatures, with the vent at various temperatures. Gas-vacuum manifolds provided flexibility in choosing the atmosphere the sodium sees, and in moving it around in the system.

1. Sodium System

The sodium system is shown in Figures 4 and 5. It consisted of a sodium reservoir, made from 6-in. pipe, which supplied sodium through a 2-in. pipe (and valve) to a sodium arm and the freeze vent, which were joined through a 2-in. tee. The reservoir and sodium arm had 1-in. diameter by 8-in. long cold-finger-type cold traps for oxide concentration control.

2. Gas-Vacuum System

The gas manifolds shown in Figure 5 provided argon at controlled pressure, roughing pump vacuum, or oxygen, to the top of the freeze vent, and argon at two pressures to the sodium reservoir. Analysis of the argon showed less than the detection limits of oxygen and nitrogen (10 wppm and ~25 wppm, respectively) and 6 wppm H_2O . Both manifolds could be vented to the atmosphere through a bubbler containing pump oil.

3. Pressure Instrumentation

The pressure of each argon source and of the oxygen source was independently measured by mechanical pressure gauges. For measurement of pressures above the freeze seal, a Validyne Model CD23 pressure transducer and digital readout system, with a range from 0 to 2000 mm Hg, was used. The transducer was calibrated against a mercury column before installation in the system. The output of the transducer was fed to a double-trace cathode ray oscilloscope (Tektronix Type 535A), and recorded by Polaroid photography. It was also recorded on a Honeywell 2-pen recorder, simultaneously with the flowmeter output.

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Figure 4. Freeze Vent Test System

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Figure 5. Freeze Vent Test System With Finned Vent Installed

4. Sodium Flow Instrumentation

An electromagnetic flowmeter was installed in the system, between the sodium reservoir and the 2-in. gate valve. The output of the flowmeter was displayed on a cathode ray oscilloscope, and recorded from the face of the cathode ray tube by means of Polaroid photography, as well as on the 2-pen recorder shared with the pressure transducer. The flowmeter was calibrated by comparing the area under the CRT output-vs-time curve with a calculated volume in the sodium system.

5. Temperature Instrumentation

Temperatures throughout the experimental apparatus were read by Chromel-Alumel thermocouples, spot welded to the vessels or piping. The thermocouple output was recorded on a Honeywell 24-point recorder and a Honeywell 2-pen recorder, which permitted two points to be recorded continuously. A choice of which thermocouples were continuously recorded was permitted by suitable switches.

B. PROCEDURE

The experiments which were performed may be classified in four main groups, the procedures for which are discussed in the following sections.

1. Plug Formation Tests

The sequence of operations for a plug formation test were as follows:

- 1) Adjust sodium (source pot) and vent temperatures.
- 2) Set the driving pressure, but leave the argon valve to the source pot closed.
- 3) Check all valves for proper position, to ensure that the freeze vent is open to the atmosphere, and that the sodium flow path is open.
- 4) Set the cathode ray oscilloscope to give a single sweep of the estimated proper duration (0.2 to 1.0 sec/cm).
- 5) Record all temperatures.
- 6) Start the oscilloscope sweep, and open the driving pressure valve, in that order, with ~ 0.2 -sec interval between operations.

- 7) Record all temperatures. Continue temperature observations to determine when equilibrium is obtained.
- 8) Determine plug location by making PVT measurements.
- 9) When temperature equilibrium is obtained, vent the driving pressure, and pressurize the gas volume above the freeze seal to 5 to 10 psig.
- 10) Turn on the vent heater (7 amp). The heater input is $1/2$ the rated voltage ($1/4$ the rated power), as required by RDT E 4-13T.
- 11) When the pressure above the freeze seal drops to 0 psig (showing that the seal has been melted out), turn off the vent heater.

2. Pressure Resistance Tests

A seal was formed in the freeze vent, in the manner described for a plug formation test; but, when temperature equilibrium was obtained, the vent heater was not turned on. To apply pressure to the sodium side of the seal, the 2-in. sodium valve was closed, and argon pressure was applied through the "sodium arm" to the underside of the sodium plug. The valving was set so that the volume above the plug consisted only of the vent itself and the line leading to the pressure transducer. The pressure reading was observed at frequent intervals. An increase in pressure would indicate that the freeze plug had been pushed upward in the vent. No movement of the plug was observed in any pressure resistance test.

3. Plug Movement Tests

A seal was formed in the freeze vent, in the manner described for a plug formation test, but with the parameters chosen so that the plug froze near the bottom of the vent. The valving was set so that the volume above the seal consisted only of the vent itself and the line leading to the pressure transducer. The temperature of the liquid sodium below the seal was raised slowly, with continuous recording of the temperatures in the freeze vent, and of the pressure above the seal. When the temperature of the frozen seal reached the melting point of sodium, there was a step change in the pressure and in the temperatures in the vent just above where the original seal had been. After such a change,

indicating that the seal had moved, the position of the new plug was determined, and the experiment repeated for the new position of the freeze seal.

4. Plug Contamination Tests

Experiments were carried out in which oxygen was added to the system from both sides of the frozen sodium plug, in an attempt to contaminate it to such an extent that breaking of the seal would be more difficult than for an uncontaminated plug. To add oxygen to the sodium side of the plug, ~ 1 gm of Na_2O_2 was added to the cold trap in the sodium arm, and the cold trap and associated piping were heated to 1100°F . After 90 hr, the sodium was allowed to cool, and the plug was melted out in the usual manner.

To contaminate the sodium plug from the gas side, a seal was made in about the middle of the freeze vent, and the volume above the plug was evacuated. Bottle oxygen was then used to pressurize the gas space to ~ 23 psig, and the oxygen was thus allowed to react with the sodium plug. The extent of reaction was followed by monitoring the oxygen pressure above the plug, and calculating, by PVT measurements, the amount of oxide formed. After several days in one test, and over 2 weeks in another, the plug was melted out in the usual manner.

IV. RESULTS

A. PLUG FORMATION TESTS

1. Finned Vent

The experimental program called for plug formation tests at three nominal sodium inlet temperatures (300, 400, and 500°F), two vent "ambient" temperatures (90 and 135°F), and over a reasonable range of sodium velocity in the vent annulus. Table 1 shows the results for the 18 tests run with the finned freeze vent. The column labeled "Sodium Temperature" is the average of the two thermocouples in the sodium source pot. The "Vent Temperature" column gives the average temperature in the freeze vent in the region in which the temperature

TABLE 1
SUMMARY OF PLUG FORMATION DATA FOR FINNED FREEZE VENT

Run No.	Sodium Temperature (°F)	Vent Temperature (°F)	Sodium Velocity in Vent (ft/sec)	Sodium Penetration Into Annulus (in.)
4	303	88	19.5	6.9
5	310	90	21.3	8
8	310	110	24.4	8.7
9	512	95	24.4	11.3
10	520	95	29	12
11	501	95	31.7	13.8
13	416	82	24.4	19.8
14	429	85	29	14.2
15	414	80	25	20
16	417	82	28.7	14.4
20	414	80	24.4	17
21	322	132	8.55	10.1
22	318	130	12.4	11.1
23	324	132	14.6	15.3
24	323	130	16.5	16.7
25	326	136	3.66	6.3
26	314	135	3.53	6.1
27	321	135	11.7	11.5

Figure 6. Finned Freeze Vent Test Data

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is relatively constant. The bottom 4 to 6 in. of the vent was heated by proximity to the heated piping region (simulating trace heating of the system in a reactor), so that the relatively isothermal region of the vent did not extend to the bottom of the annulus. The position of the seal in the vent was, of course, affected by the length of the nonisothermal region of the vent, which in turn was determined by the relative positions of the bottom of the annulus and the surface of the insulation on the sodium system. This topic is treated in more detail in Section V.

Figure 6 shows the results from the finned freeze vent, with the measured height of the top of the sodium plug plotted against the computed sodium velocity in the vent as it first enters it. The three sets of data for which lines are drawn in the figure have been calculated by a least squares procedure, grouping experimental points according to reasonably close values of sodium temperature and vent temperature. Equations for the lines shown are as follows:

Sodium Temperature (°F)	Vent Temperature (°F)	Equation [L = height (in.), u = velocity (ft/sec)]
303-310	88-110	$L = 0.219 + 0.3519 u$
501-520	95	$L = 3.229 + 0.3221 u$
314-326	130-136	$L = 3.177 + 0.7733 u$

The group of points obtained at 414 to 429°F and 80 to 85°F, shown in Figure 6, falls outside the range one might expect from the experiments at other combinations of temperatures, and do not show the same functional dependency seen in the equations listed for other sets of conditions. The sodium velocity was relatively high for these five runs — higher than was achieved in later runs with either of the freeze vents tested. Although the height of the penetration of sodium into the vent seems to depend more strongly on the vent temperature than on the velocity, it is evident that, even at vent temperatures below 85°F, the sodium velocity should not exceed 20 to 25 ft/sec at the entrance to the annulus.

For all the finned freeze vent experiments, the seal was broken in 6 to 12 min after the vent heater was energized. Great flexibility is available in

TABLE 2
SUMMARY OF PLUG FORMATION DATA FOR
UNFINNED FREEZE VENT

Run No.	Sodium Temperature (°F)	Vent Temperature (°F)	Sodium Velocity in Vent (ft/sec)	Sodium Penetration Into Annulus (in.)
28	320	90	11.45	3.8
29	320	90	19.1	5.7
30	386	90	18.6	8.7
31	371	90	19.1	7.3
32	418	130	3.23	8
33	428	132	4.3	7.8
34	417	133	11.1	9.6
35	421	125	12.5	16.2
36	410	143	12	21.2
37	422	140	7.15	24.3
38	413	140	3.59	12.9
39	423	142	5.05	14.1
40	421	142	5.05	12.2
41	421	142	6.45	18.2
42	520	142	2.31	12.4
43	512	142	2.31	12
45	524	141	4.38	20.5
46	520	143	3.6	18.8
47	331	144	2.92	9.3
48	294	141	3.67	10.1
49	298	140	6.77	13.8
51	309	89	16.3	7.3
53	304	82	7.52	7.3
54	303	85	8.52	6.6
55	305	93	6.52	5.7

the time required to break a seal, since the heater is run at a small fraction of its rated power. The control and readout on the heater power were not chosen to provide precise input information, so it is not possible to compare seal breaking times with any degree of accuracy.

2. Unfinned Vent

The major thrust of the tests with the unfinned freeze vent was to determine whether the presence of fins was a significant factor in the performance of the vent. The results of the 25 experiments in plug formation carried out with the unfinned vent are shown in Table 2. These data are plotted in Figure 7, with straight lines drawn through groups of points obtained under similar conditions. Equations for the lines shown are as follows:

Sodium Temperature (°F)	Vent Temperature (°F)	Equation [L = height (in.), u = velocity (ft/sec)]
303-320	82-93	$L = 6.193 - 0.0109 u$
417-428	125-133	$L = 5.14 + 0.6759 u$
410-423	140-143	$L = 9.468 + 1.173 u$
512-524	141-143	$L = 2.647 + 4.215 u$
294-331	140-144	$L = 5.829 + 1.176 u$

The two points at about 380°F and 90°F (Runs 30 and 31) are too close together to define a line, but they fall reasonably close to the group at 303 to 320°F and 82 to 93°F. No anomalously large values for the height are seen, as were observed with the finned vent. Most of the experiments with the unfinned vent were made with the vent at elevated temperatures, since such conditions test the effectiveness of the freeze vent more strenuously. It is surprising to note that there is no apparent dependence of height on velocity for the ambient temperature (90°F) plug formation runs. In the finned vent, there seemed to be a dependence, although the velocity range of the data was not extensive.

As in the experiments with the finned vent, all plugs were melted out easily in 6 to 12 min.

Figure 7. Unfinned Freeze Vent Test Data

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B. PRESSURE RESISTANCE TESTS

The ability of a frozen seal to resist pressure from the sodium side was tested, to verify Equation A-4 of RDT E 4-13T. These tests were performed with the seal formed in Run No. 26. The results are shown in Table 3.

TABLE 3
PRESSURE RESISTANCE TESTS

Sodium Pressure (psi)	Duration (hr)	Vent Temperature (°F)	Plug Movement
100	24	90	No movement of the plug was observed over the entire test.
300	24	90	
500	2	90	

According to Equation A-4 of the Standard, a plug 0.5 in. long should withstand ~400 psi at a temperature above 200°F. Since the sodium is driven into the vent during seal formation, to a point well above that at which the temperature equals the melting point of sodium, the length of the seal is several inches, soon after it is formed. Only under extreme temperature conditions, such as were needed for the seal movement tests described in the next section, is the seal length reduced to a point at which pressure might cause seal movement. These pressure resistance tests served to show that no anomalous and unforeseen phenomena occur when the frozen seal is pressurized from the sodium side.

C. SEAL MOVEMENT TESTS

Five freeze seal plugs were subjected to conditions designed to cause the plug to melt, and to move further up the vent annulus. For these tests, it was necessary to form the plug near the bottom of the freeze vent, in order to permit the greatest movement of the plug to be observed. In Runs 55, 57, 58, 59, and 60, a low plug was obtained, and subsequently moved. In Run 56, the original plug formed too high in the vent. It was melted out, and a fan was installed to maintain the bottom of the vent at a low temperature for the formation of the original plugs for subsequent tests.

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Figure 8. Recording of Sodium Flow and Argon Pressure During Run No. 59 (Two plug movements shown)

After the original plug was formed, the temperature of the sodium in the piping leading to the freeze vent was slowly raised, until the plug itself approached the melting point of sodium (208°F). The sodium was then observed to move upward in the vent, and to form a new plug at a higher position. Additional heating caused the plug to move again. The most important observation made in the seal movement tests was that the sodium plug did not creep upward in the vent; but that it moved, in a fraction of a second, to a new position several inches further along the annulus.

Results of the seal movement tests are shown in Table 4. Although the basic phenomena of sudden plug melting, flow, and reforming were demonstrated, sufficient experimentation was not done to define parameters and predict results quantitatively. Instrumentation was not completely adequate to follow temperatures, pressures, and flows precisely, over the period of time needed. However, the double movement seen in Run 59 is well documented in the 2-pen recording shown in Figure 8. This subject is further treated in the next section.

TABLE 4
SEAL MOVEMENT TESTS

Run No.	Temperatures at Time of Movement (°F)		ΔP Across Seal (psi)	Height of Sodium in Annulus (in.)		Distance Moved (in.)
	Sodium Source	Vent		Before Movement	After Movement	
55	800	125	6.3	5.7	13.8	8.1
	1123	130	6.3	13.8	No further change	
57	645	105	30	3.4	17.6	14.2
58	728	100	30	3.2	20.3	17.1*
59	750	150	4.0	3.8	8.1	4.3
		150	4.0	8.1	10.4	2.3
60	760	140	9.0	3.2	9.2	6.0

*In Run 58, the plug apparently moved 2 or 3 times within a period of a few seconds, as judged from observing the flowmeter trace on the oscilloscope.

D. SEAL CONTAMINATION TESTS

Attempts were made to contaminate freeze vent plugs with oxygen, both from the sodium side, such as might be caused by the freeze vent's acting as an informal cold trap in a sodium system, and from the argon side, such as would occur with air leakage into the gas lines, or from impurities in the gas. In the limited time available for equilibrating the frozen sodium plug with dissolved oxygen in the sodium, or gaseous oxygen, only small amounts of contamination could be obtained. Although a relatively large amount of oxygen was present in the liquid sodium below the freeze vent annulus (~ 500 wppm oxygen), in the 90 hr allowed for transfer of the oxygen to the underside of the freeze plug, it is estimated that <1 mg would have transferred by concentration gradient diffusion. Although other mechanisms of transfer were probably operating also, it is unlikely that as much as 1 mg of oxide was present at the solid-liquid interface. After the sodium cooled to 400°F , the seal was broken easily in <10 min heating by the usual procedure.

Two tests were run in which the gas side of the freeze vent plug was contaminated with bottle oxygen. The amounts of oxygen reacted, determined by PVT measurements in the calibrated gas volume, were 12 and 35 mg of oxygen, respectively. In both cases, the seal was broken by energizing the vent heater for <10 min.

It does not appear to be possible, in a limited time, to provide freeze vent plugs that are contaminated in the same fashion that one would expect after several years of operation of a reactor sodium system. The tests reported here do not necessarily show that freeze vent plugs will be easily melted out, after being frozen for extended periods of time.

V. DISCUSSION AND EVALUATION

The experiments described have demonstrated that a freeze vent, built to the requirements of RDT E 4-14T (February 1971), will operate satisfactorily. However, the results of the tests indicate that more positive restrictions on vent geometry should be included in the Standard. These are discussed later.

A comparison of the results of tests with the finned vent and the unfinned vent permits some generalizations to be made. The operation of the two vents was essentially the same, when it is realized that the major effect of the fins was to lower the position in the vent at which the "Vent Temperature" in the tests was reached. The penetration into the annulus was measured from the bottom of the annulus, in all cases. The temperature of the vent decreased, from a value approaching the sodium temperature at the bottom of the annulus to the recorded vent temperature, over a distance of several inches. A first approximation of the position of the effective bottom of the annulus is the zero velocity intercept of the velocity-height lines. From the equations presented earlier, it is seen that this point is ~ 3 in. into the vent for the finned version, and ~ 6 in. into the vent for the unfinned version. The fins do impress a steeper temperature gradient on the lower end of the vent, but do not affect the heat transfer from the sodium to the walls. The time involved in the formation of a plug is so short (generally, 0.03 to 0.4 sec) that the heat that can be transferred through the metal and radiated by the fins is negligible. The operation of the finned and unfinned vents is thus judged to be equivalent, other parameters being equal.

In the vent design tested, the bottom of the annulus is 3 in. above the top of the insulation on the sodium system, permitting easy access to the fitting which connects the vent to the system. In a reactor application, this fitting is replaced by a weld; and, to ensure that the plug can be melted out, no matter what the sodium system temperature is, the vent annulus (heater) extends below the insulation. This fact is important to consider, in regard to the height at which the plug will form, since the effective bottom of the annulus will be above the geometric bottom.

The experiments show that the most important parameter for effective seal formation is the ambient temperature of the vent. This fact suggests that the temperature of a vent must be closely watched, during a system-fill operation. Even though the ambient temperature of the vent might be adequately low at the beginning of a fill operation, it is possible that the venting of gas through it during filling might heat it above a satisfactory seal-forming temperature. The possibility that the vent temperature will be raised in this manner must be considered, in any case.

Of importance at the higher vent temperatures is the velocity of the sodium in the vent annulus. The temperature of the entering sodium appears to play an important, but lesser, role in determining the position of the plug. Although the planned experimental program was not extensive enough to develop firm quantitative data from which predictions of freeze vent performance could be made over a wide range of conditions, even for the one annulus size tested, it does show some specific limits for the operation of the vent. For a vent 2 ft in length, with an annulus 0.055 in. wide, the sodium velocity in the annulus should not exceed 25 ft/sec at the low vent temperature of 85 to 90°F, with the inlet sodium temperature in the 300 to 500°F range. For a relatively high vent temperature of 140+°F, the velocity should not exceed 12 ft/sec for 300°F sodium, 8 ft/sec for 400°F sodium, and 3 ft/sec for 500°F sodium.

The phenomenon of plug movement, as the sodium is slowly heated, is one of special interest to sodium system operators. When a freeze plug is initially formed, the heat removal required to freeze sodium at the leading edge of the annular column may be divided into two parts: (1) cooling sodium to the melting point, and (2) removing the latent heat of fusion. In the circumstance of plug movement by incipient melting, only the latter quantity of heat must be removed to re-form a plug after it has been melted. Several attempts were made to correlate the movement of the plug with calculated or assumed heat transfer and fluid flow parameters, but no success was achieved in predictions of plug movement. Thus, the conclusions to be drawn from the plug movement tests are largely qualitative. It is seen that the frozen sodium plug does not creep, but moves quickly (in <0.1 sec, estimated from oscilloscope traces) from one position to another higher in the vent. The distance moved is a function of the pressure differential across the plug when it moves. The way to prevent seal

movement is to maintain the frozen sodium plug at a temperature below the melting point, since the movement does not occur until the plug melts. The shear strength of sodium is sufficient to resist several hundred pounds per square inch of pressure, to very near the melting point, with only a small thickness of frozen plug.

The problem of melting the frozen plug, in order to have an open freeze vent for system maintenance, is not as clearly solved as that of making the original seal. There was no trouble encountered in opening the vent in any of the tests carried out in this program, but the effect of oxide buildup over long periods of operation could not be studied. The attempts to contaminate the frozen seal with oxygen, both from the sodium side and the gas side, succeeded in transferring only a small amount of oxygen to the plug. The limitations of the tests were the results of the inherent slowness of the diffusion and reaction processes that are involved. Even if it were feasible to deposit a larger amount of oxygen at either the liquid-solid or the liquid-gas interface, the process which grows the cement-like material in cold traps, or at gas interfaces after long exposure to an impure atmosphere, cannot be speeded up.

The problem of movement of the plug after it is formed, as the result of the temperature increase occurring as the reactor system comes up to power, may be met in at least two ways. Of course, a plug that is high enough in the vent so that the temperature at the plug location can never exceed say, 170°F, will never move. If the system operation during plug formation is controlled to form a plug in the upper half of the vent, and the temperature of the vent is properly monitored, no problem of failure by having the sodium move out of the vent will be encountered. It may not always be possible, in practical operating situations, to choose conditions so that the plug will form in the optimum location — in the top half of the vent — every time. A backup provision to prevent failure by plug movement is needed. This may be accomplished by minimizing the gas volume above the vent, and closing it with a valve or (preferably) a welded seal. If the frozen plug should melt, and the sodium rise in the vent, the gas above it would be compressed, and would resist the movement. The sodium could, in no circumstance, rise above the point at which the gas pressure above it was equal to that in the sodium system; and the braking effect

on the sodium flow would probably cause re-freezing, before the pressures were equalized..

The experimental program described has successfully demonstrated that a freeze vent of the dimensions tested does work. Operating parameters within which the vent operates satisfactorily are outlined, within the limitations of the test program. However, it is felt that the requirements of RDT E 4-13T (February 1971) need to be revised, to prevent the design of vents with an unacceptably wide annulus. The experimental results show that the heat transfer assumptions implied in Equation A-5 of the Standard are not valid for the system. It is now possible to call out a range of vent widths which will provide an operable vent, without needing to rely on an estimated freezing time as required in the Standard. The recommendation has been made to eliminate Part III of the Appendix to the Standard, which includes Equation A-5, and to include in the Appendix a statement limiting the width of the annulus to a maximum of 0.060 in. and a minimum of 0.015 in. The requirements of each application for gas flow rate, and for sodium mass flow rate, may be met by increasing the diameter of the vent while maintaining the annulus at an acceptable width. The use of a narrower annulus will provide faster plug formation for a given linear flow rate, but should also be more subject to difficulty in opening the vent, although the experimental program was not designed to show this.

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