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ATOMICS INTERNATIONAL A Division of North American Aviation, Inc.		NAA-SR- TDR NO 11936	APPROVALS <i>J. Leppard</i> <i>E. J. Klee</i>
TECHNICAL DATA RECORD		PAGE 1 C 15	
AUTHOR G. E. Turner	DEPT & GROUP NO 781-13	DATE 4/29/66	
		GO NO 7593	
TITLE Gas Entrainment in the SCTI Secondary Sodium System		S/A NO 1322	TWR
		SECURITY CLASSIFICATION	
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		AEC DOD	RESTRICTED DATA ☐
		UNCL. ☒ ☐	DEFENSE INFO. ☐
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PROGRAM Sodium Components Development		AUTHORIZED CLASSIFIER SIGNATURE DATE	
SUBACCOUNT TITLE Sodium Component Test Installation		<i>H. P. Prachuan</i> 22 May 66	
DISTRIBUTION D. F. Casey* J. C. Cochran* C. C. Conners* R. Cygan* R. W. Dickinson* H. B. Dietz* H. B. Holz* L. L. Johnson* A. L. Kohl* G. Landler* J. A. Leppard* W. T. McSweeney* R. L. Rehorst* G. E. Turner*		STATEMENT OF PROBLEM To determine the extent and magnitude of gas entrainment in the SCTI secondary sodium system and its effect on the SCTI testing program.	
		ABSTRACT Tests showed that at sodium flow rates greater than about 1700 gpm, gas is entrained at the steam generator free surface and is transported to the secondary expansion tank. Some of the gas also remains in circulation throughout the secondary system. The rate of gas transport to the expansion tank and the amount of gas in circulation both increase rapidly with sodium flow until system instability is reached at a sodium flow of about 2700 gpm with the steam generator level control at its normal setting. Increasing the steam generator level control setpoint to its practical maximum, an increase of about 4", increases the point of system instability to about 3200 gpm and keeps gas entrainment rates reasonable up to about 2800 gpm sodium flow. This is sufficient to allow performance of all planned tests except the reduced superheat operation.	

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Test Purpose

The purpose of this test was to define the extent and magnitude of gas entrainment in the SCTI secondary sodium system. During prior brief periods of high flow operation of the secondary sodium system, observations were made that there appeared to be a gas entrainment problem. However, these periods of high flow operation were not of sufficient duration to obtain more than a qualitative estimate of the degree of gas entrainment.

System Description

The SCTI secondary sodium system consists of a free-surface pump, the tube-side of the intermediate heat exchanger (IHX), the shell side of the steam generator and an expansion tank (T-5). Figure 1 shows the arrangement of these components and their relative locations.

Figure 2 is a representation of the upper part of the steam generator showing the location of the inlet sodium nozzle, the upper tube sheet, the rupture disc nozzle, and the sodium level gauges. A gas space is maintained in the upper part of the steam generator to protect the upper tube sheet and the upper rupture disc from the high temperature and rapid temperature changes of the incoming sodium. Since the steam generator is not at the high point of the system, the steam generator sodium level must be controlled by regulating the gas pressure in this gas space. This gas pressure is controlled, and the level maintained, by a controller which utilizes the sodium level signal from the displacer-type level gauge to position an argon supply and a vent valve.

Test Method

All normal argon supplies to and vents from the secondary sodium system were valved off. The vents were checked to verify that there was no significant argon leakage from the secondary sodium system. An argon bottle was then connected temporarily to supply the gas space above the sodium free surface from which the gas was being entrained. We had previously observed that the gas was being entrained in the steam generator and transported, at least partially, to the secondary expansion tank. Therefore, the argon bottle was connected to the steam generator

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UPPER STEAM GENERATOR OUTLINE

FIGURE 2

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Test Method (cont'd)

sodium level control argon supply. Thus the amount of gas entrained could be determined by the pressure change, and therefore gas quantity, in the argon bottle.

For the tests which determined the rate at which gas was entrained and transported from the steam generator to the secondary expansion tank, system parameters were allowed to reach an equilibrium condition before data was collected. In the last test, which was to determine volume of gas continuously circulating throughout the system, data was taken prior to and immediately following the flow increase.

Test Results

The test data are attached at the end of this report. The secondary expansion tank level was measured with a precision level probe and the measurement given is from an arbitrary reference point down to the sodium level. Thus, a larger number means a decrease in sodium level in the expansion tank. The steam generator sodium level measurement is from the displacer-type level gauge and is given in percent of its 12 inch range.

Sodium flow is given in percent of full scale of a 0-30 millivolt recorder. Translation of this millivolts signal to a sodium flow in gpm is based upon rather limited heat balance data taken during low power operation. Based upon this limited data, a flow calibration of 5600 gpm full scale on the 30 millivolt recorder has been derived. This calibration, however, could be in error by as much as 10%.

The gas transfer rates are based on an argon bottle content of 330 standard cubic feet at a bottle pressure of 2640 psig. These values were obtained from Air Reduction Company, the argon supplier. This means that each 100 psig reduction in argon bottle pressure corresponds to 12.5 scf of argon being supplied to the steam generator via the level control system.

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Test Results (cont'd)

The first data was taken at 1400 gpm, with no gas transport from the steam generator to the expansion tank as evidenced by the constant expansion tank pressure. The gas consumption of 6.7 standard cubic feet per hour (scfh) was assumed to be system leakage. Later tests at flows below the flowrate at which gas entrainment occurs show system leakage somewhat below this value - in the range of 2 to 4 scfh. This difference was attributed to greater leakage at the temporary argon bottle connection.

The second run was attempted at 2800 gpm, however, system operation became very erratic and large volumes of gas were being entrained (as shown by a rapid increase in the secondary expansion tank level). The flow was then reduced to about 2000 gpm and data was taken at that level. During this run, the expansion tank level decreased nearly to the level observed in run #1, indicating that the gas entrained at 2800 gpm was being de-entrained. During the time of the major de-entrainment, no gas was supplied from the argon bottle. The argon bottle pressure increased slightly during this time, apparently due to the recovery of the bottle temperature after being cooled somewhat due to the heavy gas usage at 2800 gpm sodium flow.

Subsequent runs at various flow rates provided the data shown as curve 1 in Figure 3. As shown by this curve, gas entrainment starts to climb rapidly above about 2000 gpm when the steam generator sodium level is maintained at 50% on the displacer-type level gauge. Operation at more than 2600 gpm with the above steam generator level produces excessive gas consumption rates and erratic system operation.

Four runs were then made to determine if operation with a higher steam generator sodium level would appreciably affect the gas entrainment rate. The results of these tests is shown in Figure 4. These tests showed that an increase in steam generator level from 50% to 93% (only about 5") caused an 80% reduction in the rate of gas entrainment at 2400 gpm.

FIGURE 3

Argon Consumption vs. Sodium Flow

Curve 1 - Steam Generator Sodium Level of 80%

Curve 2 - Steam Generator Sodium Level of 85%

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Test Results (cont'd)

In view of these results, it was decided to determine the relationship between sodium flow and rate of gas entrainment with the steam generator sodium level maintained at the highest value felt to be practical: 85%. The data from these runs is shown on curve 2, Figure 3. Operation at this steam generator sodium level allows operation to about 3000 gpm although 2800 gpm is probably a more reasonable maximum flow.

The final test was performed to determine the approximate volume of gas circulating around the system as opposed to the rate of gas transport from the steam generator to the secondary expansion tank. The test was started by operating the secondary sodium system at about 1700 gpm, the flow rate at which gas entrainment just starts with the steam generator sodium level at 50%. After all system parameters had stabilized, data was taken and then the flow was increased to about 2500 gpm in about one minute. Over the next 20 minutes, the secondary expansion tank level increased 4 inches indicating that about 9 cubic feet of gas was being circulated around the system with the sodium. The sodium inventory of the secondary sodium system is about 460 cubic feet; thus the gas constituted about 2% by volume. This level of gas content should not have a significant effect on the heat transfer characteristics of the IHX or steam generator.

Conclusions

The maximum secondary sodium flow rates specified for the various tests in APAE 122, "Test Program for 30 Megawatt Prototype Sodium Intermediate Heat Exchanger and Steam Generator" are as follows:

<u>Test</u>	<u>Maximum Secondary Sodium Flow</u>	
	<u>Pounds/hour</u>	<u>Approximate gpm</u>
Balanced Sodium Flow	1,110,000	2,630
Unbalanced Sodium Flow	1,000,000	2,370
Part Load Thermal Performance	1,140,000	2,700
Reduced Superheat Operation	1,370,000	3,300

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Conclusions (cont'd)

Operation with a steam generator sodium level of 85% will allow flow rates up to the maximum required for all tests except the reduced superheat tests, provided that the flowmeter calibration error is not greater than estimated.

It is recommended that the reduced superheat tests be reviewed to determine whether the tests can be performed at reduced secondary sodium flow rates or whether the tests should be eliminated.

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CHECKED BY								REPORT NO NAA-SR-TDR-11936	
DATE April 29, 1966			Data Sheet					MODEL NO	
Run	Time	Flow	Sec. Expan. Tank Level	Steam Gen. Level	Sec. Expan. Tank Press.	Steam Gen. Press.	Argon Bottle Press.	Aver. Argon Consump.	Aver. Sodium Flow
1	1350	25%	92 in.	45%	5.5 psig	30.0 psig	2490 psi		
	1420	25%	92	53	5.5	30.0	2460		
	1450	25		47	5.5	30.0	2420	6.7 scfh	1400 gpm
	1520	25	91½	50	5.5	30.0	2410		
2	0925	50	86½	57	9.6	50.0	2360		
	0945	35.0	81½	48	5.7	37.0	1820		
	1000	35.0	84½	49	6.0	36.5	1830		
	1030	36.0	90	49	7.0	38.0	1850		
	1100	36.2	91	48	8.0	38.7	1810		
	1130	36.6		48	8.7	39.5	1770	12.9	2040
	1230	36.7	91½	50	9.8	41.0	1660		
	1330	36.4	91½	49	11.3	42.0	1540		
3	1345	40.3	90	50	7.0	40.5	1540		
	1400	40.2	90½	50	7.9	41.5	1470		
	1430	40.3		49	9.7	43.0	1330		
	1500	40.4		49	11.6	45.3	1200	33.3	2260
	1530	40.2		49	13.4	47.0	1060		
	1600	40.3	90½	50	13.6	47.3	940		
		The secondary expansion tank relief valve starts to lift at about 13 psig.							
4	0815	45.5	90½	48	4.8	42	810		
	0820	44.8	89½	50	5.5	42.5	740		
	0825	44.5	89½	50	6.3	43	690		
	0830	44.5	89½	50	7.1	44	630	91.3	2490
	0840	44.5	89	49	9.7	45.5	510		
	0850	44.6	89½	50	10.3	47	390		

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DATE April 29, 1966								MODEL NO	
Data Sheet									
Run	Time	Flow	Sec. Expan. Tank Level	Steam Gen. Level	Sec. Expan. Tank Press.	Steam Gen. Press.	Argon Bottle Press.	Aver. Argon Consump.	Aver. Sodium Flow
4									
(cont'd)	0900	44.4	89	49	12.0	49	270		
	0910	44.6	89½	49	13.3	50.5	140		
5	0950	45.5	88	48	6.2	44	2380		
	1000	45.8	88½	48	8.3	46	2220	113.6	2560
	1010	45.8	88½	49	10.4	48.5	2080		
	1023	45.9	88½	49	13.5	51.5	1880		
6	1110	46.9	88½	49	7.0	46	1430		
	1120	47.2	88½	49	9.1	48	1260		
	1130	47.2	88½	48	12.0	51	1080	130	2640
	1140	47.0	88½	49	13.6	52.5	910		
7	1500	16.9	91	52	8.1	29	920		
	1530	17.0	91	48	8.1	29.3	910	1.7	960
	1630	17.6	91	52	8.0	29.3	900		
8	0830	29.0	91	51	9.0	35.3	900		
	0930	29.0	91½	49	9.1	35.5	900	2.2	1630
	1030	29.0	91½	49	9.3	35.5	880		
	1130	29.3	91½	49	9.5	36	860		
	1230	29.4	91½	50	9.6	36	830		
9	1240	33.0	91½	49	6.9	35.3	840		
	1310	32.8		50	8.8	37	800	6.9	1840
	1410	32.9	91	50	9.3	38	750		
	1440	32.8	91	50	9.7	38.5	730		

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Run	Time	Flow	Sec. Expan. Tank Level	Steam Gen. Level	Sec. Expan. Tank Press.	Steam Gen. Press.	Argon Bottle Press.	Aver. Argon Consump.	Aver. Sodium Flow
10	1500	37.8	91	50	6.6	38	690		
	1530	38.0		50	9.0	41	600		
	1600	38.0	91	50	10.0	42	530		
	1630	38.0		50	10.9	43	450	20.0	2130
	1700	38.3	90%	50			400		
	1730	38.0		50			310		
	1800	38.1		50			210		
11	0930	36.0		49	5.2	35.5	2500		
	1000	35.8		50	8.7	39	2430		
	1030	36.0		50	9.4	39.5	2390	11.7	2010
	1100	35.8		50	9.9	40	2350		
	1130	36.0		50	10.3	41	2300		
	1230	36.2		50	11.5	42	2220		
12	1300	42.0		50	7.4	42	2030		
	1340	42.3		50	10.2	46	1810		
	1410	42.3		50	13.7	48.5	1630		
	1430	42.2		50	13.9	48.5	1530	39.2	2360
	1500	42.2		50	14.0	48.5	1390		
	1530	42.2		50	14.0	48.5	1230		
	1600	42.3		50	13.9	48.5	1090		
13	0930	43.5		50	7.1	43	920		
	0945	43.7		50	9.3	45.5	800		
	1000	43.7		50	11.0	47	680	57.5	2450
	1015	43.6		50	12.8	49	570		
	1045	43.7		50	14.0	50	340		
	1100	43.7		50	14.0	50	230		