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ADVANCED REACTOR SYSTEMS DEPARTMENT

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MASTER

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SUBJECT: DOE Contract DE-AT03-76SF70030, Work Package No. AF
15 40 10.1, LMFBR Steam Generator Systems Development, WPT
No. SG037, Large Leak SWR Test and Analysis

*"Supplementary Information on Series II Test A-5
Test Conditions"*

- REFERENCES:
- 1) Letter XL-796-10088, W. V. Leeburn (GE) to S. G. Harbison (SAN), "Proposed LLTR Series II Test A-5 Test Conditions," September 3, 1981.
 - 2) Memorandum NE-530 (RRT:E:261), John A. Ford (RRT) to J. B. LaGrone (SAN), "LLTR Series II A-5 Test," September 21, 1981.
 - 3) Letter XL-796-10100, W. V. Leeburn (GE) to S. G. Harbison (SAN), "Response to DOE Comments on LLTR Series II Test A-5 Test Conditions," October 7, 1981.
 - 4) Telecon, H. H. Neely (ETEC) and J. C. Amos (GE), November 9, 1981.

Dear Mr. Harbison:

Test planning and test preparation for LLTR Series II Test A-5 are continuing at GE and ETEC. The main objective for this test is to obtain data on the type and magnitude of steam tube blowout failures resulting from worst case leak conditions under the superheater hot standby condition (i.e., the plant condition considered most susceptible to steam tube blowout failures from wastage/overheating). A corollary objective is to add large quantities of steam (i.e., ~330 lbs) to simulate the amount that could be added in a plant system (such as CRBRP) before pressure would buildup in the Intermediate Heat Transport System to blow the expansion tank rupture disc.

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third tank would feed the secondary tubes with a nitrogen system maintaining pressure (and supplying nitrogen diluting the steam) when the pressure dropped below 1450 psi. However, following the issue of Reference 1 and 2 it was established that the maximum amount of steam that could be added in the secondary side was about 166 lbs of which about 107 lbs was diluted with nitrogen. If large secondary leaks occurred early in the test, the secondary supply system would be exhausted relatively early with the test falling short of its goal of 330 lbs total primary/secondary steam addition.

Various options for arrangement of the primary and secondary water systems have been identified as shown in Figure 1. The estimated capabilities for water/steam supply for the different options are tabulated in Table 2. Option 1 is the original steam/water supply arrangement described above. The primary supply pressure could be increased to 2000 psi to increase the primary steam supply inventory. In Option 2 the primary steam supply is the same as for Option 1; however, to increase the secondary fluid supply the water inventory in Tank T3 is increased and the secondary steam inlet line and upper region of the LLTV are preheated to 900°F. This preheating could result in vaporizing about 45 lbs of the water delivered from Tank T3. Although the water supply could readily satisfy the total test requirement, the major fraction of H₂O added through a secondary leak(s) would be liquid water and non-prototypical (i.e., too conservative energy addition) with respect to the superheater hot standby condition. No LLTR facility water/steam system modifications other than addition of the N₂ pressurization system for the secondary supply tank would be required for either Options 1 or 2.

Option 3 would employ an all liquid water feed to the primary tube (lower end only) from Tank T1 with Tanks T2 and T3 devoted to feeding steam to the secondary tubes. A variation of Option 3 would be to add N₂ below the bottom of T2 (with the isolation valve closed) and series flow the steam from T2 to T3 to the secondary tubes. (This reduces the dilution effect of the nitrogen on the secondary steam.) The principal drawback to Option 3 is that addition of liquid water through the primary leak is non-prototypical (i.e., non-prototypic wastage damage/pattern) with respect to the superheater hot standby case. Again, no facility water/steam system modifications are required for Option 3 other than provision of the N₂ pressurization system for the secondary supply tanks. A smaller N₂ pressurization system (shown as optional) could be added to the primary tank (to preclude any fall off with pressure) without dilution of the primary water feed.

Option 4 feeds primary steam from a single tank T2 to both ends of the primary tube using a starting pressure of 2000 psi. The secondary steam supply Tanks T1 and T3 would be arranged in series to reduce the extent of N₂ dilution. This option requires cutting into a 4" pipe below T1 for the N₂ pressurization system, running a longer 2" N₂ line (than for the other options) and installing a 2" line from the top of Tank T2 to the lower line feeding the rupture tube. In Reference 4 ETEC indicated that this option would cost an additional estimated installation cost of 78.3K and incur an additional 5-6 weeks schedule impact over Option 1.

LLTR WATER/STEAM SYSTEM OPTIONS

OPTION #1 OPTION #2 OPTION #3

FIGURE 1

LLTR WATER/STEAM SYSTEM OPTIONS

* PRESSURE CONTROL VALVE (PCV) REPLACES
EXISTING ISOLATION VALVE V204B

FIGURE 1 (cont'd)

TABLE 2 LLTR STEAM SYSTEM CAPABILITY

Possible lbs of Steam Added (Except as Noted for Other H₂O States)

<u>Incremental Fluid Source</u>	<u>Option #1</u>	<u>Option #2</u>	<u>Option #3</u>	<u>Option #4</u>	<u>Option #5</u>
<u>Primary System</u>					
Mass Added in 200 sec (Supply tank(s) initially at 2000 psig)	193	193	>200 (liquid)	160	206
<u>Secondary System</u>					
1) Expansion 1500 → 1450 psi	6	8	9	10	—
2) Expansion 2000 → 1500 psi	—	—	—	—	165
3) Piping	14*	10	20	14	22
4) Displacement by Heel in Tank T3	7	—	—	7	—
5) Vaporization in LLTV Heat & Piping	—	45	—	—	—
6) LLTV Head	46	46(2 Phase)	46	46	46
7) Supply Tank(s)	93*	>172(Liq.)	187*	173*	195*
Total Secondary System	166	>281	262	250	428

* Diluted with N₂

The quantity of primary steam available over the initial 200 seconds is in the order of 30-40 lbs less than for Options 1, 2 and 5. The quantity of available steam is about the same as Option 3.

It should be noted that Options 1 through 4 employ the two existing 1 1/2" isolation valves (shown in Figure 1 just upstream of the LLTV). These valves (in conjunction with the new nitrogen pressurization system) will limit the secondary steam supply to about 10 lb/sec while maintaining secondary tube pressure at 1450 psig. (The maximum delivery pressure from the regulator is about 1500 psig. Allowing 50 psi drop across the valves results in a calculated steam flow rate of 10 lb/sec.) Higher secondary flow rates would correspondingly reduce the pressure in the LLTI secondary tubes. For example a 15 lb/sec flow rate would produce a calculated 112 psi drop across the valves or secondary tube pressure of 1388 psig.

Option 5 is a configuration where the primary system and secondary system are "ganged" together to feed either primary or secondary tubes on demand. A pressure control valve (PCV) must be substituted for one of the isolation valves in the secondary steam feed line. In addition the pressure control valve (used to bleed pressure off the secondary tubes during the initial SWR heatup period) must be relocated to near the LLTV as shown in Figure 1. The steam systems would be initially pressurized to 1450 psig and the new secondary steam PCV closed. Thereafter the systems would be pressurized up to 2000 psig. Water would be added from Tank T2 and converted to steam by heat transfer from the hot (900°F) piping before being fed to the upper part of the primary tube. Steam from Tanks T3 and T1 would feed the lower part of the primary tube. Secondary leaks would be fed from Tanks T1, T2 and T3.

As noted in Table 2 the quantity of steam to the primary tube under Option 5 is about 206 lbs in 200 seconds, or an average of about 1 lb/sec. (If secondary leaks occur, this capability will diminish.) The quantity of secondary steam available is estimated at about 428 lbs (less whatever has been supplied to the primary tube out of the 165 lbs associated with the expansion from 2000 psig to 1500 psig). This 428 lbs does not include any steam from Tank T2.

The secondary steam flow rate limitations inherent in Options 1-4 with the existing double 1 1/2" isolation valves (each with C_v of 60) can be overcome by replacing one of the valves with a pressure control valve with a C_v of 120 or greater. This larger valve in conjunction with the proposed N_2 supply system can supply a 15 lb/sec secondary tube leak with the pressure in the secondary tubes maintained at 1450 psig. In Reference 4 ETEC indicated that a 4" control valve, with a fully open C_v of 145 and turn down ratio of 75:1, could be obtained in about 1 month. Further, ETEC advised that the schedule impact of Option 5 over Option 1 was about 5-6 weeks and the estimated added installation cost over Option 1 was about 41.3KS.

In view of the foregoing GE recommends adoption of Option 5 as the reference steam supply arrangement for test A-5. The associated test conditions are shown in Table 3. Options 2 and 3 can be disregarded on the basis that they feed non-prototypical fluid (i.e., liquid water) from

TABLE 3

PROPOSED TEST A-5 TEST CONDITIONS FOR OPTION 5

<u>Leak Size</u>	Intermediate size leak with 0.25" diameter hole (represents ~1.0lb/sec leak rate of superheated steam)
<u>Leak Location:</u>	149" above bottom of LLTI shroud in peripheral tube 4175 between spacers 4 and 5.
<u>Leak Orientation:</u>	Directed at second row tube 4163.
<u>Sodium Conditions:</u>	
Temperature:	625 ± 10°F
Pressure:	50 ± 5 psig (Helium) initially
Sodium Fill Condition:	Fill to LLTV Upper Nozzle; cover gas in upper part of LLTV, upper header and surge tank.
<u>Primary Water Side:</u>	Feed top and bottom ends from supply tanks T2 and T1/T3, respectively. Initial flow condition: static Pressure at leak site: ~2000 ± 25 psig initially Pressure at Supply Tanks: 2000 ± 25 psig initially Inlet temperature to test article: 625 ± 30°F lower 900 ± 30°F upper*
<u>Secondary Water Side:</u>	Connected to Tanks T3 and T1 Supply temperature: 625 ± 30°F Supply pressure: 2000 ± 25 psig initially Steam Tubes: 1450 ± 20 psig
<u>Test Duration:</u>	1) Time to achieve ~330 lbs of accumulated primary/secondary leak input. Rapid isolation and blowdown (~10 sec) of primary and secondary tubes to follow 2) Failure of Na side rupture disc. Rapid isolation and blowdown (~10 sec) of primary and secondary tubes to follow 3) Low (<750 psig) pressure in secondary tubes.

* Upper steam line to be preheated to vaporize water. Temperature will decrease during test.

TABLE 3

PROPOSED TEST A-5 TEST CONDITIONS FOR OPTION 5 (cont'd)

<u>Accelerometer Location:</u>	<p>8 GE accelerometers on LLTV shell approximately in plane of leak site.</p> <p>2 AI accelerometers located on LLTI upper tubesheet</p> <p>2 AI accelerometers located on LLTV shell, axially within ± 3 feet of leak site. (One accelerometer nearest leak site; other accelerometer 180° from first accelerometer)</p> <p>2 ANL accelerometers located on LLTV shell approximately in plane of leak site.</p> <p>4 AI accelerometers located on sodium-side vent valve, secondary steam vent valve, secondary steam control valve and steam system nitrogen regulator.</p>
<u>Rupture Discs RD-1 and RD-2:</u>	Use single discs rated @ 325 psid and 375 psid, respectively.
<u>Sodium System Pressure Control:</u>	Allow pressure to build up from 50 to ~125 psig. Thereafter vent SWR produced gas to maintain pressure control with deadband between 75 and 125 psig to provide "quiet" periods for enhanced acoustic monitoring for secondary failures.
<u>Secondary Steam Nitrogen Pressurization System</u>	<p>Set nitrogen pressure regulator at maximum delivery pressure (1500 psig minimum).</p> <p>Volume and initial pressure of nitrogen adequate to maintain >1500 psig secondary side system pressure after 330 lbs of steam has leaked thru primary and secondary tube failures.</p>

primary and secondary leaks, respectively. Option 1 doesn't provide sufficient secondary steam supply capability. Option 4 extends the secondary steam supply capacity over Option 1 and probably has sufficient primary steam capacity; however, its secondary supply rate is limited to 10 lb/sec (while maintaining 1450 psig on the tubes). Option 5 provides the maximum combined total water side supply capability and maximum secondary steam feed rate capability of >15 lb/sec. Option 5 does present additional complexity with its "active" control valve systems; however, GE believes that the performance of this system can be sufficiently checked out by ETEC prior to the test.

3. Consequences of Valve Failures

A preliminary evaluation of the effects of automatic control valve failures has been performed as described in the following paragraphs:

a. Secondary System or Primary System Isolation Valves Fail to Close Following Addition of 330 lbs of Primary/Secondary Steam (All Options)

Test termination will have been initiated, including blowdown of primary and secondary tubes. Major fraction of excess H₂O/N₂ from the secondary system will be discharged through blowdown valves.

b. Control Valve Fails to Open With Secondary Leak(s) (Option 5)

Secondary tube pressure would drop; test would be terminated when pressure reaches 750 psig.

c. Control Valve Fails Wide Open (Option 5)

Pressure rise in the secondary tubes will be somewhat mitigated by opening of the secondary steam vent valve and by presence of any secondary leaks. If no credit is taken for either, the secondary water system pressure would equilibrate at about 1860 psig with an initial water supply pressure of 2000 psig, at about 1790 psig with an initial water supply pressure of 1900 psig and at lower pressures at longer periods of time from start of test. Such pressure rises from a failed open control valve would make the test conservative from the standpoint of steam pressure inside the tubes.

d. Nitrogen Regulator on Gas Supply System Fails Closed (All Options)

Pressure will drop in secondary tubes; test would be terminated when secondary tube pressure reaches 750 psig.

e. Sodium Vent Valves Fails Closed (All Options)

Sodium system will experience pressure rise until main rupture disc bursts, terminating test.

f. Sodium Vent Valve Fails Open (All Options)

Behavior of the sodium system pressure under this valve malfunction condition will depend on when this event occurs and on the extent and size of secondary tube failures produced. Pressure could fall early in the test before occurrence of secondary leaks and even rise with the advent of large secondary leaks which exceed the capacity of the vent valve. In any event, the test would be continued until 330 lbs of primary/secondary steam are added or until the main rupture disc has been ruptured.

ETEC is evaluating whether manual over-ride features can be adopted to the Option 5 secondary steam pressure control valve and the sodium vent valve. With these features, operator action could possibly extend test duration which might be otherwise shortened by malfunction of automatic controls (particularly applicable to items "b" and "e" above.)

4. Secondary Steam Nitrogen Pressurization System

The secondary steam nitrogen pressurization system described in Reference 3 has been upgraded by increasing the accumulator volume from 28 ft³ to 42 ft³ (by increasing the number of nitrogen bottles from 16 to 28). With the N₂ regulator set to deliver 1500 psig, this pressurization system can provide 18,000 SCFM N₂ at 3200 psig and 14,500 SCFM at 2000 psig accumulator pressure (the 14,500 SCFM is equivalent to a secondary steam flow rate of 17.5 lb/sec). The volume of gas provided by the reduction of pressure in the accumulator is sufficient to displace the steam in Tanks T1, T3 and the steam piping.

5. Test Termination

As described in Reference 3, test termination actions include: closing the sodium surge tank vent valve; isolating and blowing down primary and secondary steam tubes; N₂ purging of primary and secondary tubes with 400 psig N₂ supply pressure and gas pressurization of sodium system to burst RD-1 rupture disc to remove sodium and SWRPS from the LLTV. (In the unlikely event that the sodium vent valve fails open and insufficient pressure exists to burst the RD-1 disc, the sodium/SWRPS would be removed from the LLTV via the drain valve.)

The initiating signals for test terminations would be as follows:

- a. RD-1 or RD-2 rupture disc operation.
- b. Primary or secondary supply pressure (as measured by pressure sensors on inlet lines to LLTV) reduced to 750 psig.
- c. Total H₂O injection reaches 330 lbs as determined by real time computer calculation, using measured secondary steam flow to the LLTV (corrected for any nitrogen dilution) and calculated mass injected through the primary leak. Algorithms for this computer calculation will be jointly developed between GE and ETEC. Item "b" and "c" represent changes from Reference 3. Item "b" of this letter reduces the termination pressure to 750 psig to extend test durations under abnormal condictions of valve controller failure. Item "c" goes along with recommended Option 5.

GE requests approval of the recommended method of operating the LLTR steam system for Test A-5 (Option 5) and other changes of test operating conditions contained in this letter. Mr. J. C. Whipple or Mr. J. C. Amos may be contacted regarding this letter.

Very truly yours,

W. V. Leeburn, Manager
Steam Generator Projects

WVL:JCW:sgp

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